BBC

HOW TO BECOME A MORNING PERSON IN 7 STEPS

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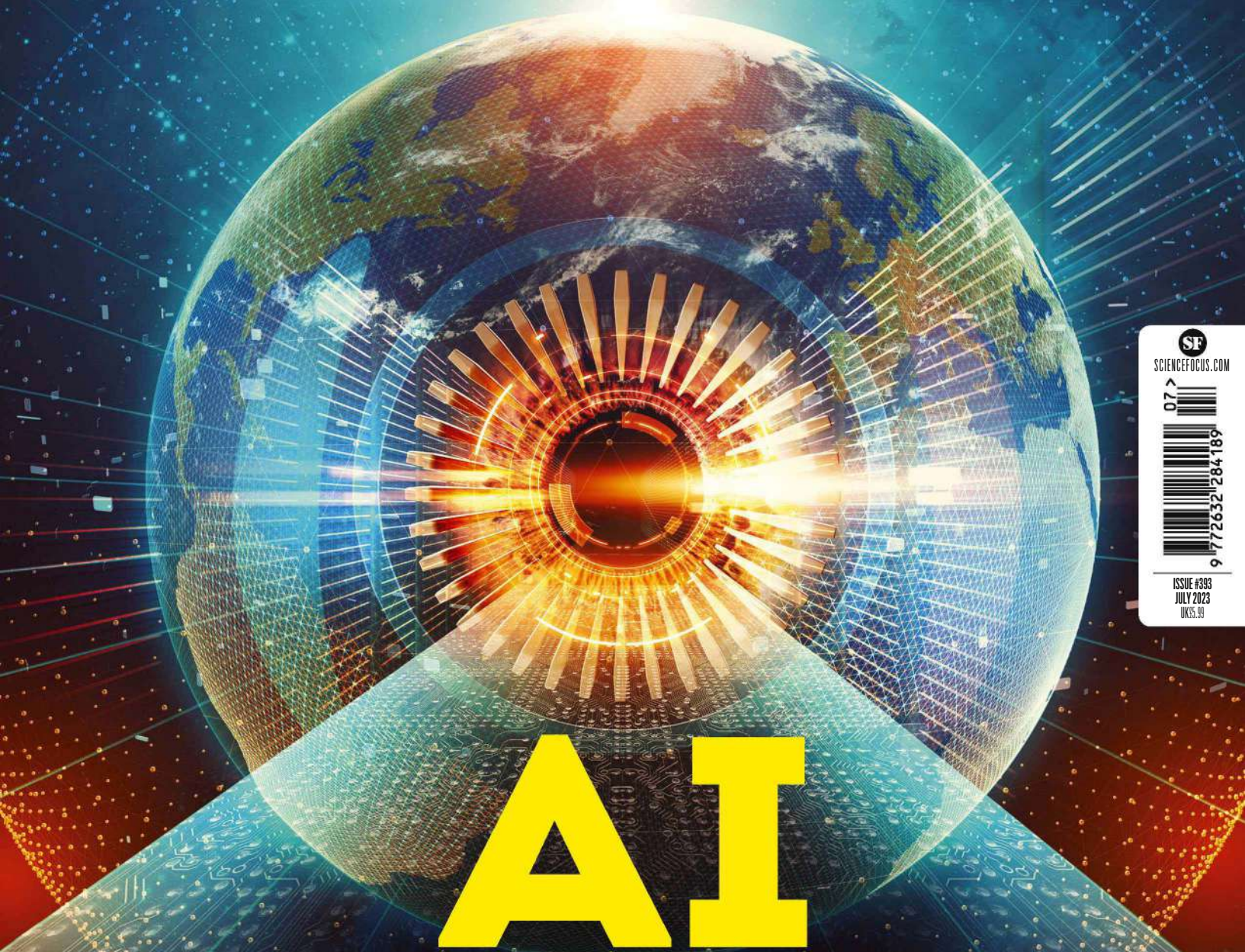

AI

WHAT OUR FUTURE WITH ARTIFICIAL INTELLIGENCE REALLY LOOKS LIKE, ACCORDING TO THE EXPERTS

How to take control before it's too late *Can computer code soothe loneliness?*
Why we can't let machines think for us *Will an AI's creation ever move us to tears?*
How post-human intellects will save us

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ISSUE #393
JULY 2023
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IN THIS ISSUE

Health
Has Ozempic accidentally become a game-changing drug?

Wildlife
Inside the secret lives of bees

Physics
What jazz musicians can teach quantum physicists

ADVERTISEMENT FEATURE

AN IMPORTANT MESSAGE FROM PROFESSOR NICK LEMOINE CBE MD PHD FMEDSCI, CHAIR OF THE MEDICAL RESEARCH FOUNDATION

Gifts in Wills could be the key to protecting the future of human health

Our experience of COVID-19 shows how suddenly a global health challenge can appear. As someone interested in science, you will understand that while nobody can predict what we will face next, we can be certain that the future will bring many more threats to human health.

As Chair of the Medical Research Foundation – the charitable arm of the Medical Research Council – I have seen the incredible impact that individuals who remember the Foundation in their Wills can have on the future of our health and wellbeing here in the UK. These gifts fund research and researchers which can have far-reaching implications for human health.

With a gift in your Will you can play a key role in providing the science that will protect the health of future generations.

Right now, the Foundation is funding research to tackle antimicrobial resistance, and investing in researchers like Dr Myrsini Kaforou – who will make the fight against antimicrobial resistance her life's work.

Without support at the crucial early stages, researchers like Dr Kaforou can be forced to abandon their passion and leave science altogether, with an immeasurable loss to future human health. Gifts in Wills provide the long term funding and security that allows the Foundation to invest in projects like Dr Kaforou's and lay the foundations for quality research in years to come.

Your Will can fund the rational response to health challenges that medical science provides.

> **"As scientists, our duty is to secure the future of research for the generations that follow."**
>
> Professor Fiona Watt, Patron of the Medical Research Foundation and Director of the European Molecular Biology Organization.

While we don't know what the future holds for human health in the UK, we do know that research, and the brilliant scientists driving that research forward, are the key to meeting those challenges for years to come.

"The funding I received through the Medical Research Foundation will be transformative for my research." Dr Myrsini Kaforou

But many of these scientists rely on the generosity and foresight of fellow members of the medical community who understand the power of science and are willing to leave a gift to medical research in their Wills. At the Medical Research Foundation, over 90% of our voluntary income comes from individuals who choose to include a gift in their Will – they are crucial in the Foundation's ability to fund research that will enable the next generation of scientists to make real world discoveries in the future.

I firmly believe that a gift in your Will to the Medical Research Foundation is an excellent investment and will have a lasting impact on science and on the future of human health in the UK.

Please consider this very special gift today.

Professor Nick Lemoine CBE MD PhD FMedSci
Chair of the Medical Research Foundation

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0723BSF

Is 'baby brain' a real thing and, if so, what causes it? →p80

FROM THE EDITOR

Artificial intelligence hasn't taken over the planet just yet. But if, like me, you listen to a lot of radio, you'd think that the machines are about to inherit the Earth. Hours upon hours of airtime have been devoted to the rise of AI: a reaction to the evolution of bots that *seem* to think, write and create like us. These bots can hold a pretty decent conversation, create digital art based on your descriptions and even compose music, and in response, every news presenter seems to believe that we've got a full-blown existential crisis on our hands. Broadcasts typically go like this: experts are brought on to say whether it really is last orders for humankind while the presenter throws around words like doomsday, armageddon and annihilation, before they wrap up and chat about the afternoon's cricket scores. Meanwhile, AI developers – you know, the people who could do something about all this – seem to be quitting their jobs en masse and throwing on sandwich boards emblazoned with 'The end is nigh'.

As you might be able to tell, it's a panic I can't really recognise. It's not that I think AI is harmless. From cybersecurity to privacy to employment, the proliferation of AI will pose serious threats. It's just that none of the conversations on TV and radio reflects the conversations I've heard from those in the know – the people at universities working with AI. So for a dose of sanity, we decided to ask some of the world's leading experts in machine intelligence to give us their takes on what issues will define the future of AI. Head to p56 to see what they said.

And if you're looking for more on the future of AI, subscribe to our podcast **Instant Genius** where we dive into the latest thinking in science and technology from around the world.

Daniel Bennett, Editor

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ON THE BBC THIS MONTH...

Yeti
Certain mythical creatures are harder to kill than others. I don't mean with a silver bullet, but stories of the Loch Ness monster, Bigfoot and the Yeti continue to be shared today. So what makes them so enduring? Two enthusiasts head to the Himalayas to try and find out.
BBC Radio 4, 1 July, 11:30pm
Also available on BBC Sounds

CrowdScience: Why do we experience vertigo?
The CrowdScience team tackles a question close to my heart: what is vertigo? And is there an evolutionary reason behind it? Anand Jagatia faces his fears to find out.
BBC World Service
7 July, 8:30pm (BST)

Understand: Tech and AI
The world is changing faster than it ever has. This bite-sized show will help you keep pace with the shifting sands of new tech, explaining how the likes of algorithms, 5G and Bitcoin actually work. Tune in if you want to find out what the difference is between machine learning and deep learning.
BBC Radio 4, 3 July, 1:45pm
Also available on BBC Sounds

CONTRIBUTORS

PROF PRITI PARIKH
Day Zero is the theoretical point when water stops coming out our taps. We're not there yet, but infrastructure engineer Priti explains how close we're getting to our reserves running dry. →p26

PROF GILES YEO
Love sprouts but hate coriander? *Trust Me I'm a Doctor* presenter Giles explains how your genes can affect your taste for greens. →p28

PROF STEPHON ALEXANDER
Theoretical physicist and musician Stephon talks us through the surprising parallels he's found between quantum physics and jazz. →p30

DR EMMA BECKETT
Nutrition scientist Emma investigates the claims that the weight-loss drug Ozempic can be used to treat a broad range of addictive behaviours and depression. →p38

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POSTMASTER: Send address changes to *BBC Science Focus*, PO Box 37495, Boone, IA 50037-0495.

CONTENTS

REGULARS

06 EYE OPENER
The best science images from around the world.

12 LETTERS
See what physical and electronic mail has arrived this month.

15 DISCOVERIES
All the month's biggest news stories: How spots help butterflies fly better; Scientists solve the mystery behind the 'simultaneous contrast' optical illusion; The world's ultimate swear word, according to maths; Fungi living beneath our feet are a huge store of CO_2; Dogs help doctors make children's hospitals better places; The *T.rex* was a coward; A daily multivitamin tablet could help stave off age-related memory loss.

28 PROF GILES YEO
Why your sense of taste is a lot more than just a matter of... well, taste.

30 PROF STEPHON ALEXANDER
How free-form jazz is helping to untangle quantum weirdness.

32 DR KATE DARLING
AI could help you deal with your emails, but it may have consequences for some languages.

34 REALITY CHECK
The science behind the headlines: Bugs on the brink; Killer asteroids; Ozempic's other uses.

41 INNOVATIONS
The latest tech and gadgets tested.

72 Q&A
Our experts answer your questions. This month: Why do I self-sabotage? Do jade rollers actually work? Is there a limit to how tall a tree can grow? Could an asteroid impact ever change Earth's orbit? Why do old batteries leak? What is guttation? And more...

82 THE EXPLAINER
Everything you wanted to know about bees.

89 CROSSWORD
Engage your grey matter!

89 NEXT MONTH
A sneak peek at the next issue.

90 POPCORN SCIENCE
With a big enough nuclear bomb, could we actually blow ourselves up?

48
SUBSCRIBE TODAY!

Get 3 issues for £5 and save 30% on the shop price when you take out a subscription to *BBC Science Focus*.

15
DISCOVERIES

A monarch butterfly's spots aren't just there for decoration. They're vital aviation aids.

34
REALITY CHECK

Where have all the insects gone? Insect numbers may be shrinking, but we can help them grow.

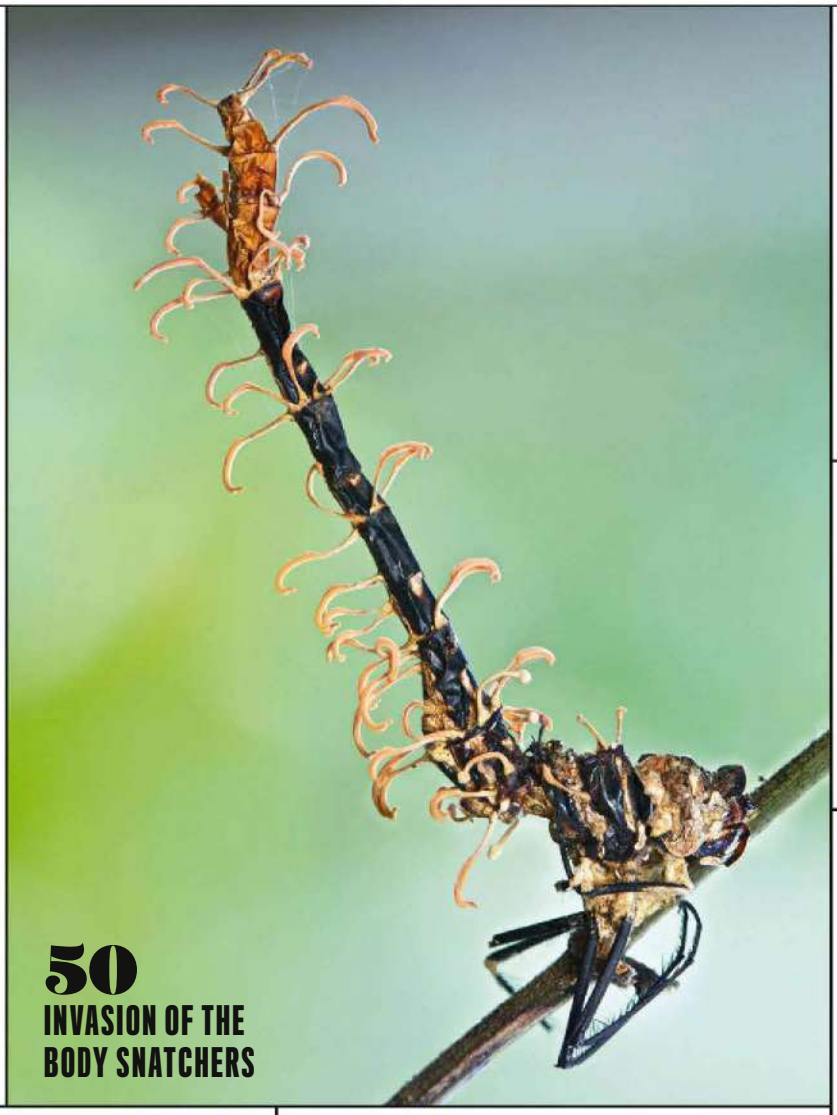
72
Q&A

FEATURES

50 INVASION OF THE BODY SNATCHERS
Fungal parasites hijack their insect hosts and use their bodies as food and vessels for reproduction... and it's as gruesome as it sounds.

56 HOW TO THINK RATIONALLY ABOUT AI
Artificial intelligence probably will change the world. But there's no need to panic about it.

66 CAN SCIENCE TURN A NIGHT OWL INTO A MORNING LARK?
There are scientific tricks you can try to help you start the day feeling bright-eyed and bushy-tailed... and we tried them.



50
INVASION OF THE BODY SNATCHERS

41
INNOVATIONS
Apple unveils its first VR headset

32
DR KATE DARLING

"WE MAY END UP IN A WORLD WHERE AI TOOLS SIMPLY COMPOSE EMAILS TO EACH OTHER"

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EYE OPENER

A land of ice and fire

HÖFN, ICELAND

Diamond Beach, on Iceland's southeastern coast, is one of the country's biggest tourist draws. But the diamonds that wash up on the shore are actually chunks of ice.

The beach lies on the inlet where the Jökulsárlón glacier lagoon, formed by run off from the Breiðamerkurjökull glacier, flows into the Atlantic. At the glacier's edge, huge chunks of ice break off into the lagoon, the largest of which eventually (after about five years) float off into the ocean as icebergs.

The smaller fragments don't make it that far. They're washed back by the incoming North Atlantic tides, onto the shore, where they stand out against the beach's black sand, which is formed mostly of basalt – a result of Iceland's volcanic activity.

Breiðamerkurjökull is one of around 30 glaciers that flow from Vatnajökull, Europe's second-largest ice cap. Vatnajökull is fast disappearing due to climate change – hence the number of 'diamonds' grows annually.

J. BANKS/AWL-IMAGES.COM

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EYE OPENER

Splashdown success

PANAMA CITY, FLORIDA, USA

In the early hours of 31 May, the crew of Axiom Space's Axiom Mission 2 (Ax-2) safely returned to Earth after a nine-day trip to the International Space Station.

Ax-2 saw SpaceX's Crew Dragon capsule Freedom launch on a Falcon 9 rocket for its second trip to the ISS. Mission commander Peggy Whitson and pilot John Shoffner were accompanied by the Saudi Space Commission's Ali AlQarni and Rayyanah Barnawi, who became the first two Saudi astronauts to visit the ISS and, in Barnawi's case, the first Saudi woman in space.

During their eight days aboard the ISS, the four crew members carried out experiments related to genome sequencing, cloud seeding and the effects of microgravity on stem cells. After a 12-hour return flight, they splashed down in the Gulf of Mexico, where SpaceX's recovery ship *Megan* was waiting to meet them.

While this was Freedom's second flight, it was the 10th crewed flight for SpaceX's Crew Dragon craft. Its next one will see the spacecraft Endurance embark on the Crew-7 mission in August.

SPACEX

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EYE OPENER

Catching a rainbow

FALMOUTH, UK

This colourful critter is a *Babakoni anadoni*, aka rainbow sea slug, that was recently spotted in a rock pool in Cornwall. While an exciting find for the amateur conservationist who discovered it, the rare sighting is also evidence of UK waters warming as a result of climate change.

B.anadoni has only been spotted in UK waters twice before and never in intertidal regions, where rock pools are found. It normally lives off the coasts of the Canary Islands, Brazil and Portugal. It's a nudibranch, a soft-bodied mollusc that sheds its shell as an adult and, more specifically an aeolid, which means that instead of gills, it uses cerata to breathe: these are the colourful, tentacle-like structures that extend along its back.

Vicky Barlow, a volunteer for The Rock Pool Project, wrote of the discovery in a blog post: "I knew exactly what the colourful blob in front of me was! Once delicately placed in a pot to view, the beautiful animal unfurled and revealed itself in full technicolour."

ALAMY

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FEEDBACK

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND *BBC SCIENCE FOCUS*

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LETTER OF THE MONTH

The bird's-eye view

I thought you may like this photo. I was reading your news story about chicken feathers (June, p16) when I noticed one of the very free-range chickens at the campsite where I was staying taking an interest. Maybe another example of animals being more intelligent than we thought?

John Rawcliffe, Ipswich

WRITE IN AND WIN!

The writer of next issue's *Letter of the Month* wins ***a trio of the latest hardback science books***. Put pen to paper (or fingertips to keyboard) and you could get your hands on *In A Flight Of Starlings* by Giorgio Parisi; *Many Things Under A Rock* by David Scheel; and *The Good Virus* by Tom Ireland.

More good news, please

Just received the March issue of *BBC Science Focus* (it takes a while for the hard copies to reach New Zealand) and love it all as usual. In particular, I really like 'The Future's Bright...' (p28). We desperately need good news these days. In fact, I'd love to see an entire issue devoted to it! It might help us all sleep a little easier.

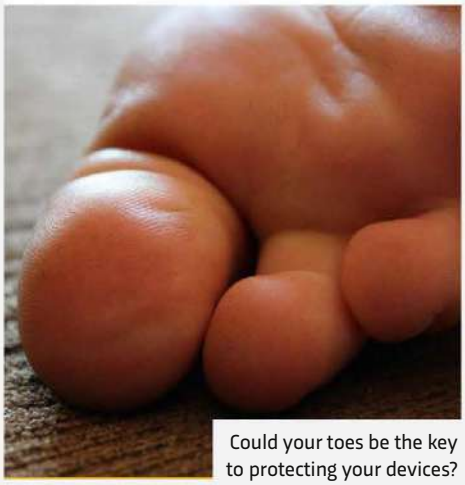
Beatrice Cheer, Christchurch, NZ

Toe-riffic

Biometric passkeys that rely on fingerprint identification (June, p36) are great... right up until you put some lotion on, use a petrol pump or start cooking dinner. Do toes have unique prints like fingers, because a toe print might actually save time?

Paul Byatt, via email

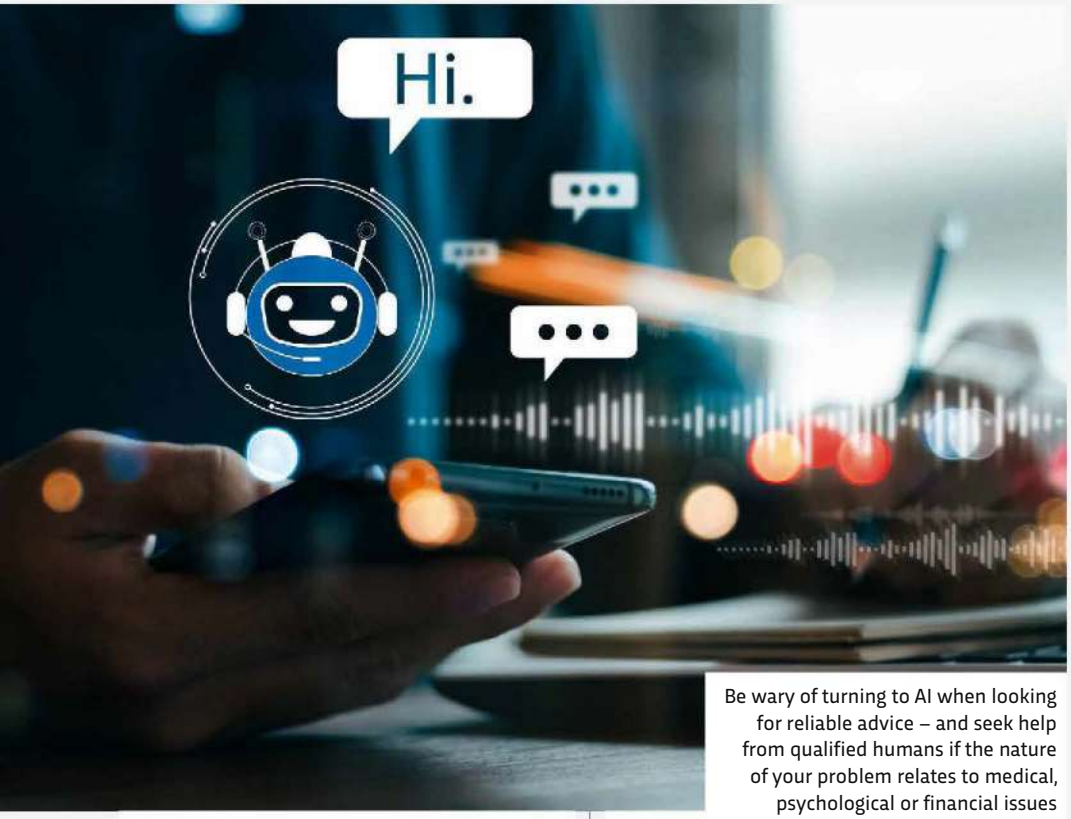
Prof Peter Bentley replies...
Actually, this idea isn't as daft as it sounds. Toe prints are as unique as fingerprints and some research studies have shown that the use of toe prints could be useful for infant biometric authentication. As for adults... well, I'm not sure I want to drop my phone on the floor, kick off my shoe and sock, and then unlock the device... especially if I have no hands free to pick it up and use it!



Could your toes be the key to protecting your devices?

"AN AI TOOL MAY BE ABLE TO COMBINE WORDS IN CREATIVE WAYS OR LEARN A STYLE FROM PAST WRITING, BUT IT WON'T INVENT SLANG"

DR KATE DARLING, P32



JOHN RAWCLIFFE, GETTY IMAGES, ALAMY

Be wary of turning to AI when looking for reliable advice – and seek help from qualified humans if the nature of your problem relates to medical, psychological or financial issues

Bad advice

I've just finished reading Dr Kate Darling's column on the potential dangers of using AI chatbots for mental health advice (April, p34). I also recently came across the news that there was just such a bot being used in the US in an attempt to help people with eating disorders, but was found to be giving poor advice. The group using the chatbot (the National Eating Disorders Association) was attempting to affirm people's body images, but the chatbot was suggesting the people with the eating disorders should cut calories and lose weight! The bot was rightfully taken offline, but it got me thinking about whether it was a problem with the bot's training or whether it could have been hacked.

Steven Ostrom via email

Dr Kate Darling replies...

Whether through hacking or simply through unanticipated responses, chatbots can cause harm to people who turn to them in vulnerable moments. The technology could also be helpful, but we don't want companies playing around with people's mental health to make a quick penny.

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ANNUAL SUBSCRIPTION RATES (INC P&P):

UK/BFPO £83.86; Europe & Eire £99.40; Rest of World £109.76

Audit Bureau of Circulations 70,284 (combined, Jan-Dec 2022)

BBC Science Focus Magazine is published by Our Media Ltd (an Immediate Group Company), under licence from BBC Studios who help fund new BBC programmes.

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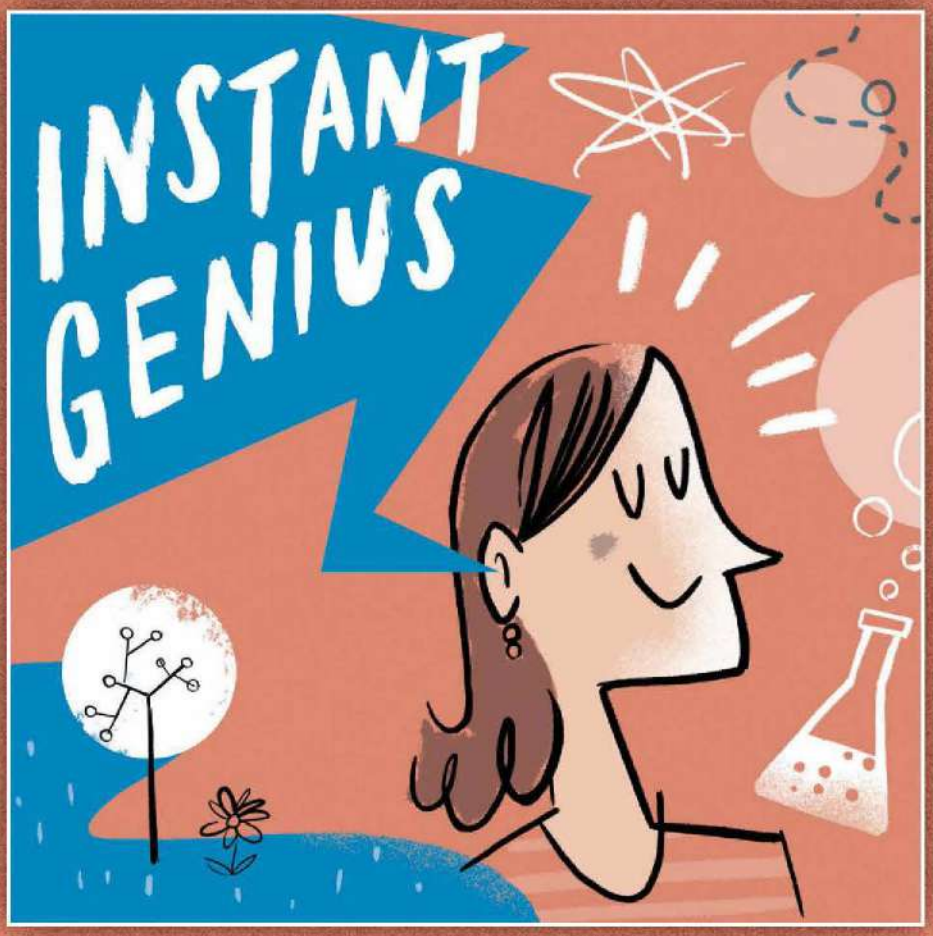

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OCEAN CURRENTS
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DISCOVERIES

"There are cases when a *T.rex* will be very conservative behaviourally, even cowardly"
Darren Naish **p22**

ENTOMOLOGY
HOT SPOTS
Sun-heated wing spots help butterflies fly **p16**

VISION
LYING EYES
How optical illusions get the better of eyes and brain **p18**

MATHEMATICS
MAY CONTAIN SWEARING
Holy $h*t! A maths researcher has found the ultimate expletive **p19**

BIOLOGY
FUNGI TO THE RESCUE
Mycorrhizal networks store vast amounts of CO_2 in the soil **p20**

MEDICINE
CANINES IN THE CLINIC
Dogs in hospitals shown to help patients and medical staff **p21**

PALAEONTOLOGY
T.REX WAS A CHICKEN
The so-called 'ultimate predator' was just as likely to run from a fight **p22**

NEUROSCIENCE
MULTIVITAMINS FOR MEMORY
A daily vitamin pill shows promise at staving off age-related memory loss **p23**

GETTY IMAGES

More than just mere decoration: the spots on butterfly wings help the insects fly vast distances

ENTOMOLOGY

SPOTTY WINGS MAKE MONARCH BUTTERFLIES MORE AERODYNAMIC

New research shows that the butterflies fly better when they have more spots on their wings

ABOVE White spots are thought to be an adaptation that helps monarch butterflies cover enormous migratory distances

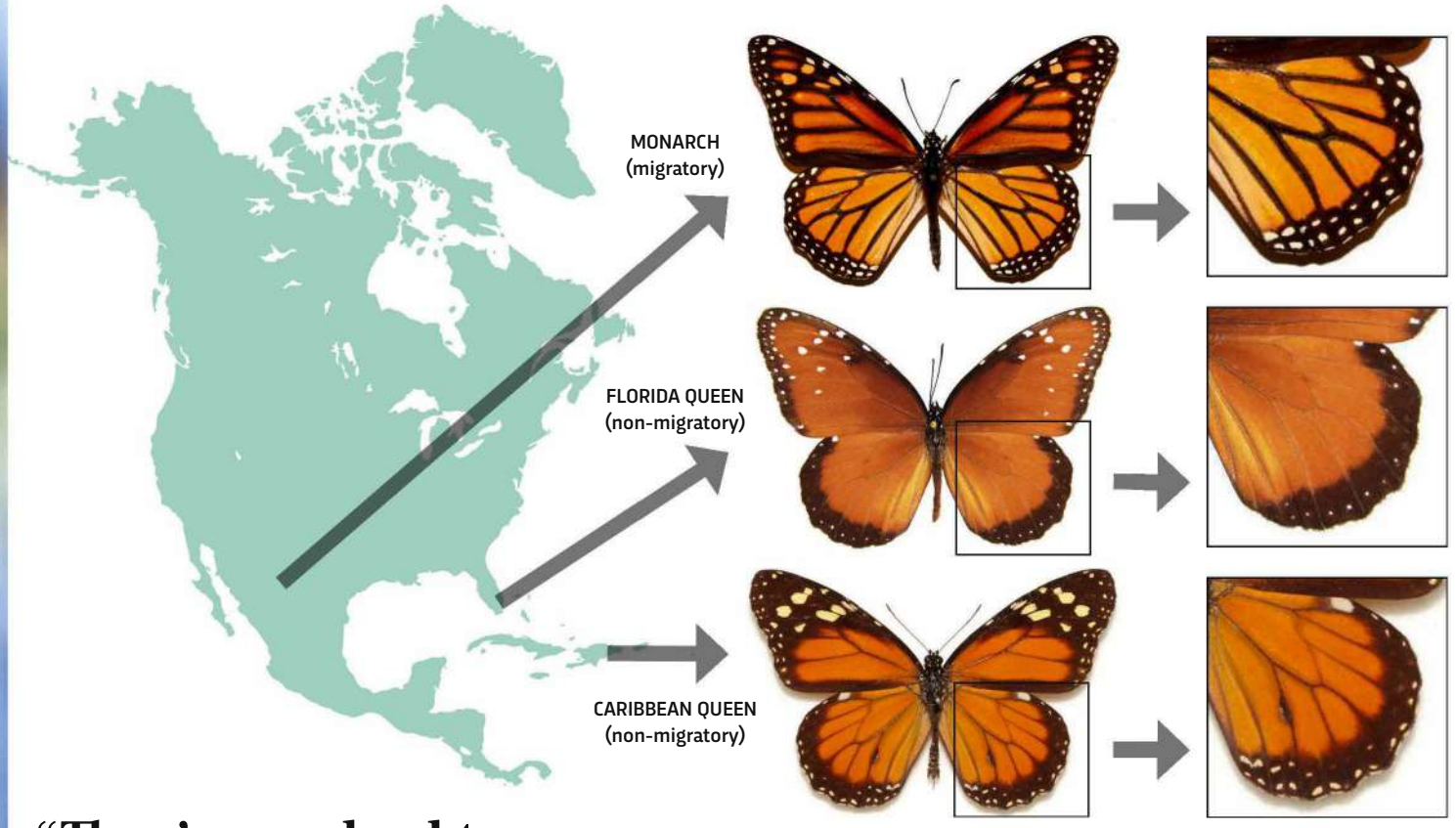
Monarch butterflies with more white spots on their wings are able to survive longer migrations, according to scientists. A study conducted by ecologists at America's University of Georgia, Athens, focused on the butterflies – which migrate thousands of kilometres every year to reach their wintering destination – found that evolution favours spottier specimens.

It's not yet clear exactly how the spots aid migration, but the authors' conjecture is that they change airflow patterns around the butterflies' wings.

"Monarch butterflies are able to fly incredible distances and this research shows that their ability may be more than just a product of the physical structure of their wings and muscles," entomologist and broadcaster Prof Adam Hart, who was not involved in the study, told *BBC Science Focus*. "Dark and light-coloured spots on their wings heat up in the sunlight differently," he continued. "This could

GETTY IMAGES, ANDREW DAVIS/BUTTERFLIESOFAMERICA.COM

Migratory monarchs have larger and more white spots than non-migratory relatives



"They've evolved to capitalise on that solar energy to improve their aerial efficiency"

cause a pattern of tiny eddies and airflow around the wings that might help the butterflies reduce drag. It's early days, but similar effects have been found in birds."

Lead author Andy Davis, an assistant researcher in UGA's Odum School of Ecology, said: "We actually went into this thinking that monarchs with darker wings would be more successful at migrating because dark surfaces can improve flight efficiency. But we found the opposite."

Monarchs travel from their native homes in the northeast of the US and southeast of Canada to south and central Mexico – over 4,800km (3,000 miles) away. The researchers behind the study, published in *PLOS ONE*, analysed the wings of around 400 wild monarchs collected at different stages along the route and measured their colour proportions.

The monarchs found at their final destination had less black on their wings, with the space instead occupied by more white spots. Specifically, these butterflies had three per cent less black and three per cent more white on their wings than those that didn't complete the journey.

The study's authors believe that white spots also help the monarchs to use solar energy to fly. "The amount of solar energy monarchs are receiving along their journey is extreme, especially since they fly with their wings spread open most of the time," Davis said. "After making this migration for thousands of years, they've [evolved] to capitalise on that solar energy to improve their aerial efficiency."

However, the authors say rising temperatures due to climate change are likely to cause a new adaptation challenge to butterflies *en route* to Mexico, with lower numbers of monarchs reaching their destination. Nevertheless, a stable population – and population growth in the summer – is a good sign for the flying insects, as long as they can reach their wintering destination.

Understanding the subtleties of the monarchs' wings could improve aerospace engineering. "Butterflies, and insects in general, are masters of flight at small scale," said Hart. "Efficient and agile, they're the perfect models for us to learn from if we want to perfect our own micro-UAVs and flying machines."

VISION

SCIENTISTS HAVE FINALLY SOLVED THE MYSTERY BEHIND THIS OPTICAL ILLUSION

A breakthrough study has discovered how 'simultaneous contrast' pictures trick your eyes

The illusion pictured here is playing tricks on your eyes. Despite initial appearances, the bar in the middle of the picture is actually just one shade of grey – it only appears lighter at one end due to the background gradient.

Such 'simultaneous contrast' illusions like this have long fascinated scientists, with many pondering why these pictures trip us up so easily. However, a breakthrough study from the University of Exeter may have unravelled the mystery: high-contrast optical illusions are caused by limitations in our eyes, rather than more complex neurological processes involving context and prior knowledge.

In simpler terms, your brain's processing power is not to blame, but rather the 'hardware' of your visual system.

"This throws into the air a lot of long-held assumptions about how visual illusions work," Dr Jolyon Troscianko, one author of the study published in *PLOS Computational Biology*, said.

As previously discovered, our eyes communicate with our brains by adjusting how fast the neurons in the brain fire. However, as Troscianko explained, "There's a limit to how quickly neurons can fire and previous research failed to consider how this might impact our perception of colour."

In the study, researchers created a computer model that mimicked the 'limited bandwidth' of the human eye, replicating the way we perceive visual information. When this model was exposed to 'simultaneous contrast' illusions, the researchers found that the model would become overwhelmed by the presence of high contrasts, resulting in a distorted perception of the image.

"Our model shows how neurons with such limited contrast bandwidth can combine their signals to

ABOVE Don't believe what your eyes are telling you – that central bar is all the same shade of grey

RIGHT Simultaneous contrast illusions like this trick you into thinking the grey bars are different shades, when, in fact, they're both exactly the same

JOLYON TROSCIANKO X2

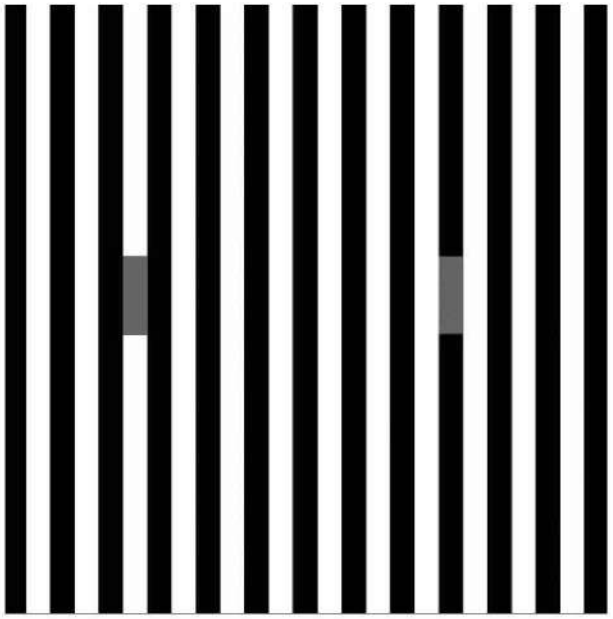
allow us to see these enormous contrasts, but the information is 'compressed' – resulting in visual illusions," said Troscianko.

The model, the researchers say, shows how different neurons have evolved to become finely tuned at processing subtle variations across a range of colours. "For example, some neurons are sensitive to very tiny differences in grey levels at medium-sized [ranges], but are easily overwhelmed by high contrasts," said Troscianko.

"Meanwhile, neurons coding for contrasts at larger or smaller scales are much less sensitive, but can work over a much wider range of contrasts, giving deep black-and-white differences."

In the future, scientists hope to use the computer model to explore the colour perception of animals with different vision neuron bandwidths to humans.

"There's a limit to how quickly neurons can fire and previous research failed to consider how this might impact our perception of colour"



MATHEMATICS

THE WORLD'S ULTIMATE SWEARWORD... ACCORDING TO MATHS

Searching for a new curse to use in frustrating situations? This mathematician's code may hold the answer

A mathematics researcher has developed a formula she claims has created the world's best swear word. MSc student Sophie Maclean, who is due to begin her PhD in number theory later this year at King's College London, wrote a code that can read a list of existing swearwords and analyse their qualities to create a new one.

So what world-beating expletive did the code come up with? According to maths, the ultimate swearword is 'banger' – or 'ber' for short.

The answer may be disappointing for anyone expecting something coarser. "I think neither is as satisfying as a 'f*ck' when you've stubbed your toe, or a 'sh*t' when you realise you've forgotten your parent's birthday. But both feel like they could be quite good insults," said Maclean.

To determine the profanity, Maclean used a Markov chain: a mathematical model that predicts the probability of a sequence based on previous inputs. In this case, the Markov chain assessed the likelihood of each letter following the one before it – a bit like predictive text.

The Markov chain was given a sanitised list of swearwords gathered from Ofcom's guide to using offensive language on TV and radio, which is based on surveys of public attitudes to certain words and phrases. Maclean cleaned up the list to remove what she deemed to be highly offensive swearwords (anything racist, sexist or ableist), using only 45 of the 186 English words listed in the guide.

In the guide, these words are ranked by several offence levels. These rankings are reflected in Maclean's code, with more offensive words given a heavier weighting. She also integrated algorithms into the code to calculate the likely characteristics of the ultimate curse, which she expected to begin with 'b', have four letters, and end in -er (what Maclean calls 'the w*nker-t*sser phenomenon').

Maclean discovered that there were in fact two letters equally likely to come after 'b': 'a' and 'e' – meaning a tie between 'banger' and 'ber'. Maclean shared an initial version of the code at the Cheltenham Science Festival in early June. This early code produced randomised words as the first letter was not restricted to 'b', yielding alternative new curses like 'ditwat'.

As Maclean points out, 'banger' already has some lewd connotations while 'ber' provides the opportunity for a fresh start: a great one to teach your children, perhaps.

BIOLOGY

HIDDEN FUNGI ABSORB OVER A THIRD OF EARTH'S FOSSIL FUEL EMISSIONS

A new study pinpoints a major carbon pool in the filament networks of mycorrhizal fungi found underneath mushrooms

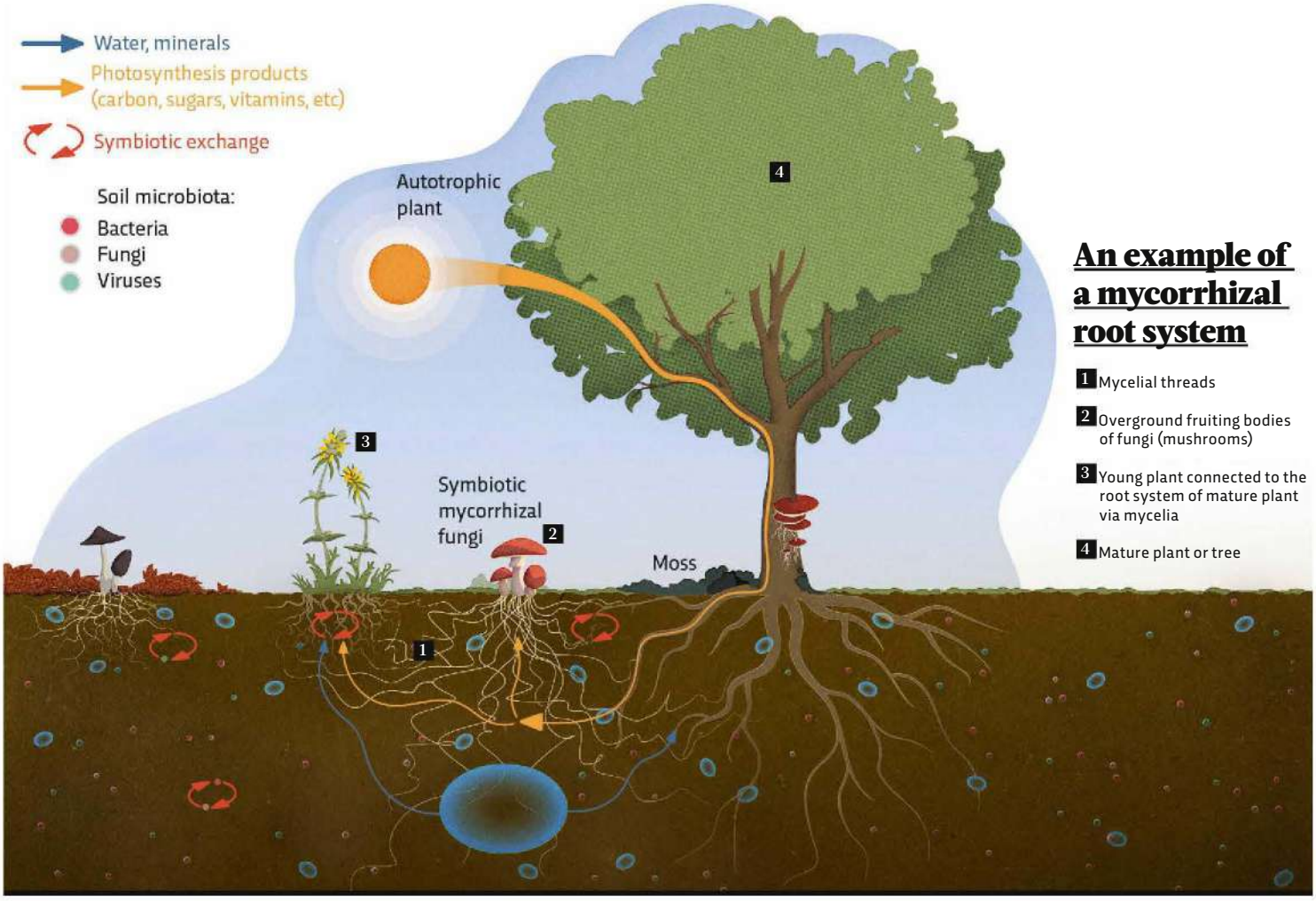
Powerful fungal networks hidden underground are storing some of humanity's carbon emissions, and could help us lock away even more if we protect them, according to a new study.

Researchers from the UK, South Africa and the Netherlands have revealed that plants absorb an estimated 13 billion tonnes of carbon dioxide equivalents (CO_2e) from the atmosphere annually and deposit them in mycorrhizal fungi in the soil. The amount of carbon being allocated to these networks is equivalent to 36 per cent of annual global fossil fuel emissions.

Mycorrhizal fungi form mutually beneficial partnerships – known as symbiotic relationships – with the roots of plants. The fungi supply the plants with nutrients that are essential for the plant's growth and, in return, take some of the sugars that the plants produce through photosynthesis, as well as the carbon dioxide they absorb in the process.

"Understandably, much focus has been placed on protecting and restoring forests

"Plants absorb an estimated 13 billion tonnes of carbon dioxide equivalents annually and deposit them in mycorrhizal fungi"



GETTY IMAGES, SHINE ON KIDS ILLUSTRATION: DAN BRIGHT

as a natural way to mitigate climate change," said Dr Heidi Hawkins, research associate on plant-soil-microbe interactions at the University of Cape Town, South Africa, and one of the study's authors.

"But little attention has been paid to the fate of the vast amounts of carbon dioxide that are moved from the atmosphere during photosynthesis by those plants and sent below ground to mycorrhizal fungi."

Scientists have known for a long time that these fungi form symbiotic relationships with plants, but only in recent years have they discovered that these relationships also act as the gateway for carbon to enter the soil. The study published in *Current Biology* estimates just how much carbon the plants are allocating to the fungi.

Mycorrhizal fungi transport nutrients and minerals through the soil using extensive filament networks called mycelium, which they expand using carbon. For some fungi, these networks sit beneath their fruiting bodies (mushrooms), which release spores to help the fungi reproduce.

But there's still more to learn. "While mycorrhizal fungi certainly contain and release carbon into the soil, we don't yet know whether mycorrhizal fungi are a carbon

Mushrooms are the fruiting bodies of mycorrhizal fungus

store [that maintains a constant amount of carbon] or sink [that absorbs more carbon than it releases]," Hawkins told *BBC Science Focus*. "That said, there are already some practical actions we can take by, for example, conserving areas where we know that those specific mycorrhizal associations result in a high allocation of carbon to the soil, such as forests and heathlands."

The researchers emphasise the need for more research as the UN Food and Agriculture Organisation (FAO) warns that 90 per cent of soils could be degraded by 2050.

MEDICINE

PUPS IN SCRUBS: DOGS COULD MAKE CHILDREN'S HOSPITALS BETTER FOR EVERYONE

Dogs have been bringing their owners comfort at home for centuries. Now, the pooches are branching out to do it hospitals

A new study shows that hospital facility dogs can ease pressure on medical staff as well as improve the lives of patients and their families.

Hospital facility dogs are not your average pooches. They're trained animals, working full-time in hospitals with several responsibilities. At the Shizuoka Children's Hospital in Japan, where this study was conducted, the dogs' duties include visiting patients, walking with children to surgery, and cuddling distressed children to help them fall asleep.

"The dog's ability to be a 'friend' to the children is a great strength," Dr Natsuko Murata-Kobayashi of Japan's non-profit children's care organisation Shine On! Kids, told *BBC Science Focus*.

"It's easy to say that the loving and empathetic nature of a dog makes them good at this work, which is absolutely true, but there's a great deal of training and experience behind the scenes that ultimately determines the power and success of their work."

Led by Murata-Kobayashi alongside scientists at Kansai University, Japan, the study surveyed 431 full-time medical staff at Shizuoka.

It found that 73 per cent of staff thought the dogs were helpful in improving patient co-operation during procedures and examinations. Over half of the respondents had worked directly with the dogs.

The majority of the respondents also lauded the dogs for helping to bridge the gap between the medical staff and patients (the study observes that children were more communicative after their canine cuddles).

The authors of the paper conclude that this model of dog service use is effective in supporting patients in children's hospitals, though further research is needed to understand and improve specific duties the dogs can deliver.

Yogi, a facility dog at Shizuoka Children's Hospital visits a patient and their mother

"Jog on, mate. I'm having that carcass"

PALAEONTOLOGY

THE *T.REX* WAS ACTUALLY A COWARD... SOMETIMES

According to palaeontologists behind Apple TV+'s *Prehistoric Planet 2*, the *Tyrannosaurus rex* was more than willing to run from a fight

On a beach in North America over 66 million years ago, a *Tyrannosaurus rex* abandons the carcass of a giant sauropod due to the arrival of a *Quetzalcoatlus* – a strange creature that was slightly bigger than the *T.rex* and possessed a beak that was two metres long.

This is palaeontologist Darren Naish's favourite scene in the new series of Apple TV+'s *Prehistoric Planet 2*. Naish, the lead consultant for the second series, explained the science behind the scene to *BBC Science Focus*.

"Everyone, of course, always thinks of *Tyrannosaurus rex* as the ultimate predator: an unstoppable killing machine that just bites other things in half," he says. "But no predator behaves that way.

"Every predator does things to minimise the risk of injury and death to itself. There are cases where they'll be very conservative behaviourally, almost cowardly. Because it's just not worth getting stabbed in the eye [with one of those beaks]."

Prehistoric Planet 2 focuses on creature-creature interactions like this one, asking questions such as: 'What happens when two giant apex predators are competing for the same resource?' The answers to these questions, which are depicted in the show, are based on published research – much of which Naish has been involved in.

"Everyone, of course, always thinks of *Tyrannosaurus rex* as the ultimate predator: an unstoppable killing machine that just bites other things in half"

First, the scientists had to come up with the appearance of the *Quetzalcoatlus*, which they did using research from 2008 that marked a paradigm shift in how palaeontologists think about the anatomy of these creatures. The research showed that their narrow build, with foldable 9m (29ft) wings on a leggy body, made them incredibly competent terrestrial predators that also had the ability to fly.

A more recent study, in 2015, investigated what this build would have meant for interactions with other large predators, such as the *T.rex*.

"They've both got strengths; they've both got possible weaknesses," said Naish. "But we've argued that the *Tyrannosaurus* would have second thoughts when confronted with such a tall predator. In the sequence, there's actually more than one *Quetzalcoatlus*, too, because there's evidence for social behaviour in them."

APPLE TV, GETTY IMAGES

NEUROSCIENCE

DAILY MULTIVITAMIN CAN DELAY AGE-RELATED MEMORY LOSS

Study finds that a multivitamin pill a day keeps memory decline at bay

A breakthrough study has found an affordable way to stave off memory decline: take a daily multivitamin. The three-year-long study – conducted by scientists at Columbia University, and Brigham and Women's Hospital at Harvard University in the US – found that taking multivitamins for as little as one year can delay age-related memory loss by three years.

"Losing aspects of cognition and thinking ability is one of the things that most bothers people about ageing. Despite that, there are really very few strategies that we know of that can mitigate the effects of ageing on cognition or thinking abilities," Dr Adam M Brickman – leader of the study and professor of neuropsychology at Columbia University in New York – told *BBC Science Focus*.

"What's really exciting is that, according to our study, multivitamin supplementation can maintain aspects of cognitive health with ageing – even though the effects are relatively modest."

Compared to cognitive exercises found in 'brain training' apps, Brickman said that a good diet and dietary supplementation can have a more direct effect on the brain, "keeping it healthier as we age".

This could make us less prone to diseases like Alzheimer's, though this study examined normal age-related cognitive decline rather than neurodegenerative diseases. Published in the *American Journal of Clinical Nutrition*, the study surveyed over 3,500 adults over the age of 60. Subjects were randomly assigned to take either multivitamins or placebos every day for three years.

At the end of each year the participants had to take a series of cognitive assessments to test their memory. The effects of the multivitamin supplementation became evident relatively quickly: researchers identified memory improvements after the first year.

In fact, those who took the multivitamins were about three years 'younger' than their estimated memory health levels, while the placebo-takers were on track.

Echoing the labels found on most multivitamin packaging, the researchers warn people that vitamin supplements are not good substitutes for a well-balanced diet. Brickman also advises people to consult their doctor before taking them – though, for most people, multivitamins are likely to be safe – or if they have serious concerns about their memory.

The sample population in this study were ethnically and racially similar – mostly comprised of white people of European descent. The next step for the research team will be studying the effect of multivitamins on cognition in more diverse people.

"We really need to have a more inclusive trial design to see how well this effect generalises to a more representative population," said Brickman.

A daily multivitamin pill could help delay age-related memory loss

Memory loss facts

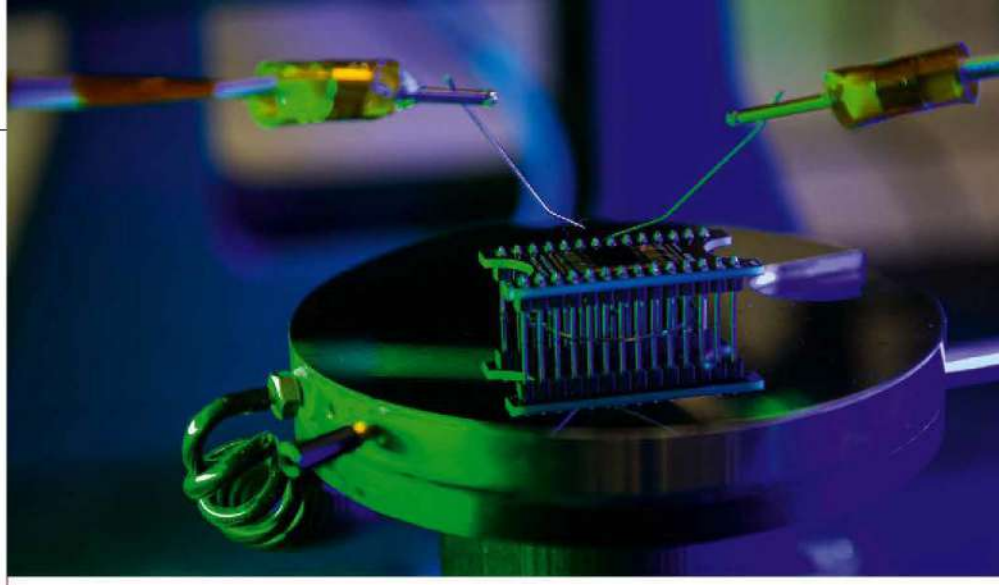
40%
of us experience memory loss after hitting 65

1 in 5
people have dementia by ages 85-89

5%
of brain volume is lost per decade after age 40

THE FUTURE'S BRIGHT...

As a remedy for all the bad news out there, let us prescribe you a small dose of feel-good science. Each issue, we'll give you a rundown of the latest breakthroughs that aim to solve humanity's biggest problems. From patches that alleviate peanut allergies to pangolin-inspired robots that perform microsurgery, here you'll find many reasons to feel hopeful about our future...



A RAPID-DECISION-MAKING MEMORY CHIP FOR AUTONOMOUS CARS

A tiny device that 'sees' and creates memories in a similar way to humans could help self-driving cars make quick, complex decisions. In order to make decisions faster, the device captures and processes visual information in a way that mimics the human eye. What's more, the packaging and transmission of the information functions like an optical nerve, while the information storage is similar to classification within the human brain. The device is thousands of times thinner than a human hair.

YEARS TO GO

25

SYNTHETIC EMBRYOS COULD TEACH US ABOUT EARLY DEVELOPMENT

Scientists have created synthetic embryos using only stem cells – with no eggs or sperm. The team from the University of Cambridge and California Institute of Technology claims that the embryo-like structures, which do not have the first features of life, could teach us about genetic disorders and miscarriages, as well as how humans begin development. However, there is currently no legislation for lab-grown entities in most countries (in the UK, they can exist for a legal limit of 14 days) and it's unclear whether these structures would continue to mature – in the preceding mice trials, the embryos didn't develop into living creatures. The research has sparked ethical alarm around the treatment of synthetic embryos.

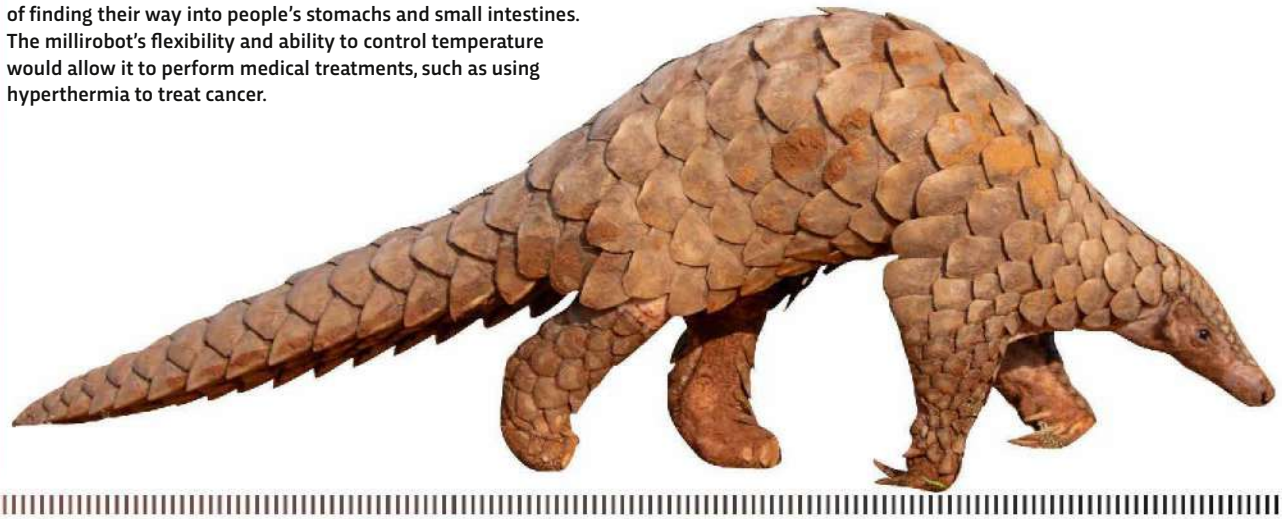
20

A SKIN PATCH FOR TODDLERS WITH PEANUT ALLERGIES

A skin patch could help to reduce the risk of severe reactions in children aged one to three with peanut allergies. Researchers at the Ann & Robert H Lurie Children's Hospital of Chicago discovered that, after a year of immunotherapy via the skin patch, toddlers who initially reacted to just a fraction of a single peanut could tolerate one to four whole peanuts. The patch, which has been deemed safe in trials, lowers the risk of severe reactions to accidental exposure to the legume, which causes allergic reactions in two per cent of children in westernised countries. There are currently no approved treatments for peanut allergy sufferers under the age of four – this could be the first.

WHERE MEDICAL ENGINEERING MEETS NATURAL DESIGN

A tiny medical robot has been developed with the aim of getting to hard-to-reach parts of the body – and its design was inspired by the world's only scaled mammal: the pangolin. Pangolins can arrange their rigid, keratin scales into overlapping structures that allow them to move flexibly. In much the same way, the millirobot (10 x 20 x 0.2mm in size) has overlapping scales and the ability to roll, as well as on-demand heating. More testing is needed, but the hope is that, one day, these soft robots could be capable of finding their way into people's stomachs and small intestines. The millirobot's flexibility and ability to control temperature would allow it to perform medical treatments, such as using hyperthermia to treat cancer.



10

SUPERABSORBENT GEL COULD PULL WATER FROM AIR

Engineers at the Massachusetts Institute of Technology have developed a gel that can soak up moisture from the air – even in deserts. The material could be used to harvest water vapour in drought-prone regions, which would then be condensed into drinking water. The engineers took hydrogel (an absorbent material used in nappies) and added lithium chloride to make it absorb record-breaking levels of moisture. "This material, because of its low cost and high performance, has so much potential," said Carlos Díaz-Marín, one of the team behind the gel. The gel could also be fitted to air-conditioning units for low-energy dehumidification.

9

BLOOD PRESSURE MONITORING AT YOUR FINGERTIPS

Turns out the camera flash on your phone is good for a more besides taking photos after dark. Engineers from the University of California San Diego have developed a device that uses your smartphone's flash to monitor your blood pressure. You press your finger against the device, which fits over your phone's camera, and it uses the flash to illuminate your fingertip. The image of your lit fingertip, in the form of a red circle, is then captured by the camera so that an app installed on your phone can analyse it to determine the amount of blood circulating inside your finger. With production costs around 60p per device, it could help to bring blood pressure monitoring to resource-poor communities.

GETTY IMAGES X5, RMIT UNIVERSITY

PRIMER

THE THREAT OF DAY ZERO

Queues at public water taps could become normal. What can we do to avoid them?

Last month saw the hottest start to June on record, the arrival of increasingly normal hosepipe bans and water infrastructure targeted in the Russia-Ukraine war. As things heat up, aquifers shrivel – and London's 90-day-supply of water means the city is never far from having its taps run dry. That's Day Zero: a benchmark that several cities around the world have come alarmingly close to – or, in some cases, already reached – in the last decade. We spoke to Priti Parikh, professor of infrastructure engineering and international development at University College London, about the looming threat of Day Zero and how household tricks and national innovations offer promising solutions.

WHAT IS DAY ZERO?

Day Zero is the countdown to when a city or location runs out of water. The term was coined initially in South Africa, in Cape Town, where there was a water crisis in 2018. The city, which had four million people, was at risk of being left without water – and this led to a series of campaigns and restrictions on water use. In January 2018, for example, Cape Town declared water restrictions of 87 litres (l) per person per day, and later decreased it to 50l per day. The actual Day Zero was estimated to happen in April or May – there were complicated calculations around the exact date because the city is dependent on water from six dams. But luckily it rained and Day Zero didn't happen. It's quite striking that a city of four million residents was left at the mercy of rains.

WHAT WOULD DAY ZERO LOOK LIKE?

Chennai, the sixth largest city in India, has between six to ten million residents and reached Day Zero in 2019. As they came closer to Day Zero, there were restrictions on water supply to houses, which meant that people had to take buckets and queue up for water collection. They had to purchase water from private vendors at very high costs. It had a big impact on local businesses and hospitals (to provide vital healthcare services, you need access to water). Once again, the city was saved by rain, but it was a very serious situation affecting mental health and wellbeing, the economics of the city, but also the social fabric of Chennai.

WHAT DOES IT TAKE FOR THIS TO HAPPEN?

As human beings, we have overexploited environmental resources on our planet. In places where we rely on groundwater, we keep on pumping and extracting it out, and this happens over a period of years. Chennai, for example, had about a thousand small lakes, wetlands and bodies of water which provided water, but in the last 30 years or so, with urbanisation, that number has reduced to 200. This is a process that has been a few decades in the making, but we're seeing an increase due to climate change as we have drier summers – and that's not helping us build up reserves of water.

Residents of Chennai collect water brought in by tanker during the city's water shortage in 2019

GETTY IMAGES

HOW CLOSE IS THE UK TO DAY ZERO?

We've had droughts over the last few summers, including a hosepipe ban for gardens and discussions about restrictions on car washing and how we use water in the garden. It's not hit drinking water yet, but the Environment Agency's national framework for water resources has identified a water scarcity crisis as a huge risk. It has said that we need to act now. So we need to boost our water resources: we need to reduce leakage, we need to reduce demand and we need this action plan to build resilience in the water supply. Otherwise, we do run a risk of running out of water in England. People may

be surprised by this because it rains a lot in England, but the amount of rain is actually not enough – and I think we're all noticing that our summers are getting drier.

WHAT ARE THE SOLUTIONS AND INNOVATIONS THAT COULD HELP US TACKLE THIS ISSUE?

There are a few things we can do. Addressing leakages in the water infrastructure system is part of it (in the UK about 20 per cent of water is lost through leaks). Then we have water meters, which enable households to look at how much water they're using to see if they can change their behaviour.

Rainwater harvesting, if done at neighbourhood or community scale, has huge potential – along with nature-based solutions. For example, sustainable urban drainage systems (SUDS) involve opening up drains in cities to collect rainfall, allow it to percolate into the ground and recharge groundwater. Landscaping is also a good option: planting trees is not only good for carbon emissions, but also helps to reduce the flow of rains and enables more water to be absorbed into the ground.

Desalination [of seawater] is often seen as a solution, but the salty brine this produces causes havoc to our environment as it builds up deposits of salt in our oceans and damages marine ecosystems.

WHAT ROLE DOES PERSONAL WATER CONSUMPTION PLAY?

Behaviour change is a big part of this. We have a high water footprint, which includes actual and virtual water consumption. For example, we need 15,000l of water to produce a kilogram of beef, and 90-150l for a pint of beer. We need to look at our consumption patterns, because in a city at the scale of London, every little bit will matter.

The UK's average water footprint is between 120-150l a day, which is high. If we benchmark ourselves against water-scarce regions, such as Jordan, that's double. Jordan is down to 50-70l, depending on seasons. But we aren't the highest. In the US, the water consumption per person is double the UK's. This is not a sustainable model.

On this planet, it feels like we have a lot of water, but the proportion of water that we can really use is about one per cent.

PROF PRITI PARIKH

Priti specialises in infrastructure for resource-constrained settings. She is also the Director of the Bartlett School of Sustainable Construction.

COMMENT

DO YOUR GENES INFLUENCE YOUR TASTE IN FOOD?

How DNA plays a role in shaping your menu choices

Have you no taste? It's an interesting, if rude, question that encompasses a broad church of possible topics. Are you about to be criticised for your taste in art? Books? Clothes? And of course, let's not forget food.

Many food tastes are acquired. Take the different types of starchy carbohydrates, which make up over half our global calorie consumption. My wife, who is of white European ancestry, loves bread. I'm of Chinese ancestry, and can take or leave it. Rice and noodles, however, I can eat every day. A love of carbs is almost universal, but the 'tastes' for its various forms are culturally embedded from an early age.

Our genes also influence our taste for certain foods. In my lab, we study the genetics of body weight, which is strongly influenced by how our brain controls our eating habits. One gene that plays a key role in controlling food intake is the melanocortin 4 receptor, MC4R, which forms part of the circuit in our brains that senses how much fat we're carrying, and so determines how long we could survive without food. We have shown that around 0.3 per cent of the UK population – up to 200,000 people – have a mutation in MC4R that makes them, on average, 18kg heavier at age 18 that someone without it. Of that 18kg, 15kg is fat.

Why? Because people with mutations in MC4R have brains that are less sensitive to the amount of fat in their body – their brains think they're carrying less fat than they actually are. As a result, they eat more and end up heavier.

The MC4R mutation doesn't only influence how much we eat, but also what we eat. A colleague of mine in Cambridge, Prof Sadaf Farooqi, devised two experiments to try and understand the role that MC4R plays in influencing food choice. She tested lean individuals and individuals with obesity, both with and without MC4R mutations.

PROF GILES YEO

(@GilesYeo)

Giles is a professor of molecular neuroendocrinology at the University of Cambridge, and has presented Trust Me, I'm a Doctor *and episodes of* Horizon *on BBC Two.*

DISCOVER MORE

RADIO

Listen to Giles explain why our genes make us fat on The Life Scientific*: bit.ly/LifeSciGenes*

BBC RADIO 4

In the first experiment, she offered participants an all-you-can-eat buffet with three kinds of chicken korma. The three curries all looked, smelled and tasted the same, but differed in fat content, which was manipulated to provide 20 per cent (low), 40 per cent (medium) or 60 per cent (high) of the calories from fat. Those carrying a mutation in MC4R ate almost twice the amount of high-fat curry than the lean individuals, and 65 per cent more than individuals with non-MC4R obesity.

The same three groups were then given Eton mess, a pavlova-like dessert made from strawberries, whipped cream and meringue. Again, there were three options, this time differing in the amount of sugar present, providing eight per cent, 26 per cent or 54 per cent of calorific content. In contrast to the first experiment, individuals with a mutation in MC4R liked the high-sugar dessert less than their lean and obese counterparts, and ate less of all three than the other two groups. It turned out that people with a defective MC4R gene preferred higher fat foods, but had a decreased preference for sugar.

How about the taste or distaste for specific foods, such as the divisive Brussels sprout? During a talk at the Royal Institution in London, I once performed a demonstration with 12 people from the audience. Everyone was given a small piece of paper to put on their tongue. I did it too, to show I wasn't trying to poison anyone. Half of the volunteers (including me) encountered an acutely bitter taste, while half tasted nothing and were puzzled by the others' reactions. What was going on?

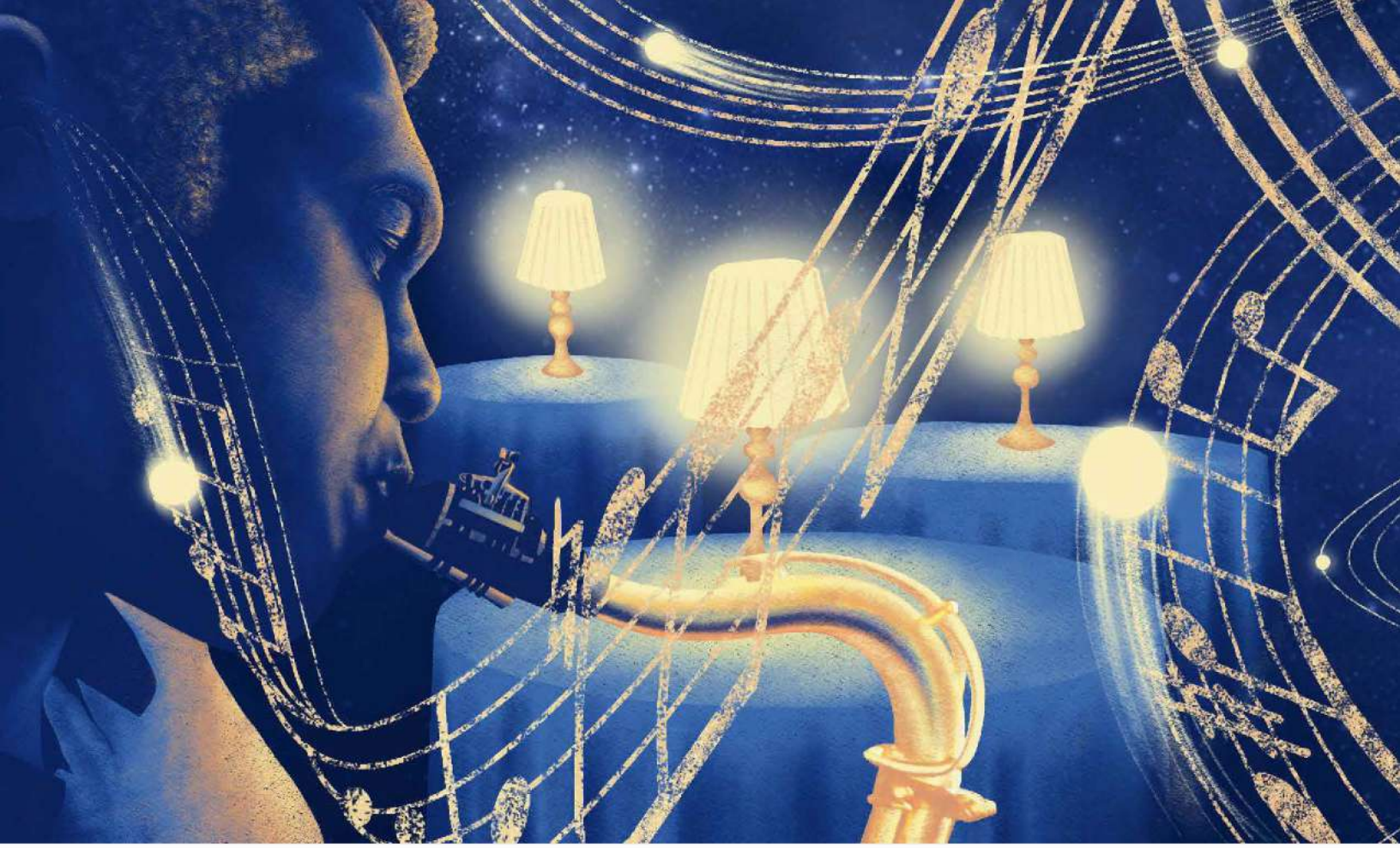
Well, all the pieces of paper were infused with a drop of phenylthiocarbamide. That's the chemical responsible for the bitter taste found in brassica – plants in the cabbage and mustard family, which includes Brussels sprouts. Around 50 per cent of people carry a variation of the gene TAS2R38 that allows them to detect this bitterness. Being able to taste this bitterness doesn't automatically mean you'll hate sprouts, but it certainly influences the sensation you get from eating them.

Then there's the 'Marmite' reaction people have to the herb coriander (also known as cilantro), which many people consider tasty, but some – famously the chef Julia Child – find disgusting. For coriander-phobes the herb has a soapy taste, and this too is genetic. Some people have a variation in the olfactory receptor gene OR6A2 that allows them to strongly perceive the aldehydes in coriander leaves – the source of the soapy flavour. Interestingly, the prevalence of this variation varies geographically, and it's less common in regions where coriander is more popular, such as Central America and India.

So next time a dinner companion expresses a like or dislike for a specific food, it could be for cultural reasons, but it could have a genetic basis. Whatever the reason, it's probably best not to judge!

"For coriander-phobes the herb has a soapy taste, and this too is genetic"

ILLUSTRATION: SINEM ERKAS



COMMENT

JAZZ COULD BE THE KEY TO UNDERSTANDING QUANTUM PHYSICS

An improvising soloist can play any note they want next. At the quantum level, electrons have a similar freedom

My book, *The Jazz of Physics*, looks at the ways that concepts and research in theoretical physics parallel jazz improvisation and performance. Playing jazz has shaped the way I approach physics and opened me up to appreciating an improvisational style in my research. And jazz continues to effect my research in uniting quantum physics with space-time and quantum gravity.

It all started from a conversation I had with a jazz legend, which has since grown into a collaboration and a new theory. One autumn day in 2012, while I was a professor at Haverford College in Philadelphia, I received a surprising email from Donald Harrison. To many, including myself, Harrison is a living version of iconic bebop saxophonist Charlie Parker. He has played with hundreds of jazz masters and toured with huge names such as Miles Davis and Art Blakey.

Donald was self-studying quantum mechanics and had an epiphany he wanted to share. Little did he know that I was also a student of jazz, or that he was one of my heroes. So my eyes bulged in delight when I read his email: "I've come to realise that you don't play within the chord changes, but you play through the changes. At every moment there are infinite possibilities available to the improviser. Once a note is played, all these possibilities collapse to a measurement."

His statement struck at the very heart of quantum physics. At the time, I had been thinking about relating jazz improvisation to my research in quantum mechanics and I felt vindicated by his auspicious message. While it took many years and the writing of my book for things to mature, Donald and I have since moved on to develop a theory of quantum improvisation.

The theory had two effects. One was on the way that Donald and I compose music together and improvise, but we can save that for our performances. Here, I would like to talk about the other effect: on quantum physics.

Quantum mechanics is governed by the famed Schrödinger equation – the fundamental formula that describes the wave-like nature of electrons as they move around an atom's nucleus. Yet despite its experimental and technological successes, there remains a debate. Started by Niels Bohr and Albert Einstein, it boils down to how to relate mathematics to the real world.

A real quantum experiment consists of a microscopic system (a molecule, for example) and a measurement device (an observer). While quantum mechanics is governed by one equation, there are different formulations that lend themselves to a given interpretation of Schrödinger's equation in the real world.

ILLUSTRATION: MATT HOLLAND

"Jazz improvisers consider many possibilities for a melody at any given moment"

Perhaps the most successful formulation of quantum mechanics is the famous physicist Richard Feynman's idea of the 'path integral' – a theory so successful that it enabled quantum mechanics to mature into the quantum field theory of the standard model of particle physics. Thanks to this idea, we have a clearer interpretation of quantum mechanics – and what it says is berserk.

In a nutshell, macroscopic particles – those large enough to see with the naked eye – move through space on unique trajectories. For example, an aeroplane traverses a unique path from New York to London, simply because there's one aeroplane involved. But the Feynman path integral describes a quantum particle, say an electron, that instead traverses every possible path between its first and final destination. Accepting this interpretation forces us to accept that an electron can be many places at the same time!

Here is where quantum improvisation can come to the rescue. The idea is that experienced jazz improvisers consider many possibilities for a melody at any given moment. This happens so quickly that the improviser doesn't have time to think, but to simply play 'through' the development of the harmonic movement.

After many years of practice and committing to memory the countless melodic pathways that occur through chord changes, a bebop musician becomes more and more skilled at playing through the changes. So the quantum improvisation interpretation of the path integral is simply that quantum entities improvise their journey through space-time, informed by the quantum rules that govern their interaction with other quantum particles and space-time itself.

It's not only Donald and me on this jazz-physics journey. A year ago, I received an email from Dr Scott Oshiro, a brilliant young jazz musician and quantum engineer who recently earned his PhD from Stanford University's Center for Computer Research in Music and Acoustics. Scott has developed an algorithm that runs on a quantum computer and is able to quantum improvise based on input from live instruments.

This all shows that while engaging in crosstalk between fields may at first appear to be disparate, and comes with risks, the rare cases when it works out are dumbfounding. Time will tell where the quantum improvisation framework will take us. But in the meantime, it's providing a great avenue for Donald and I to make interesting new sounds and to inspire the next generation of young investigators to explore new directions in music and science.

STEPHON ALEXANDER
(@stephstem)
Stephon is a professor of physics at Brown University, an author and an accomplished jazz saxophonist.

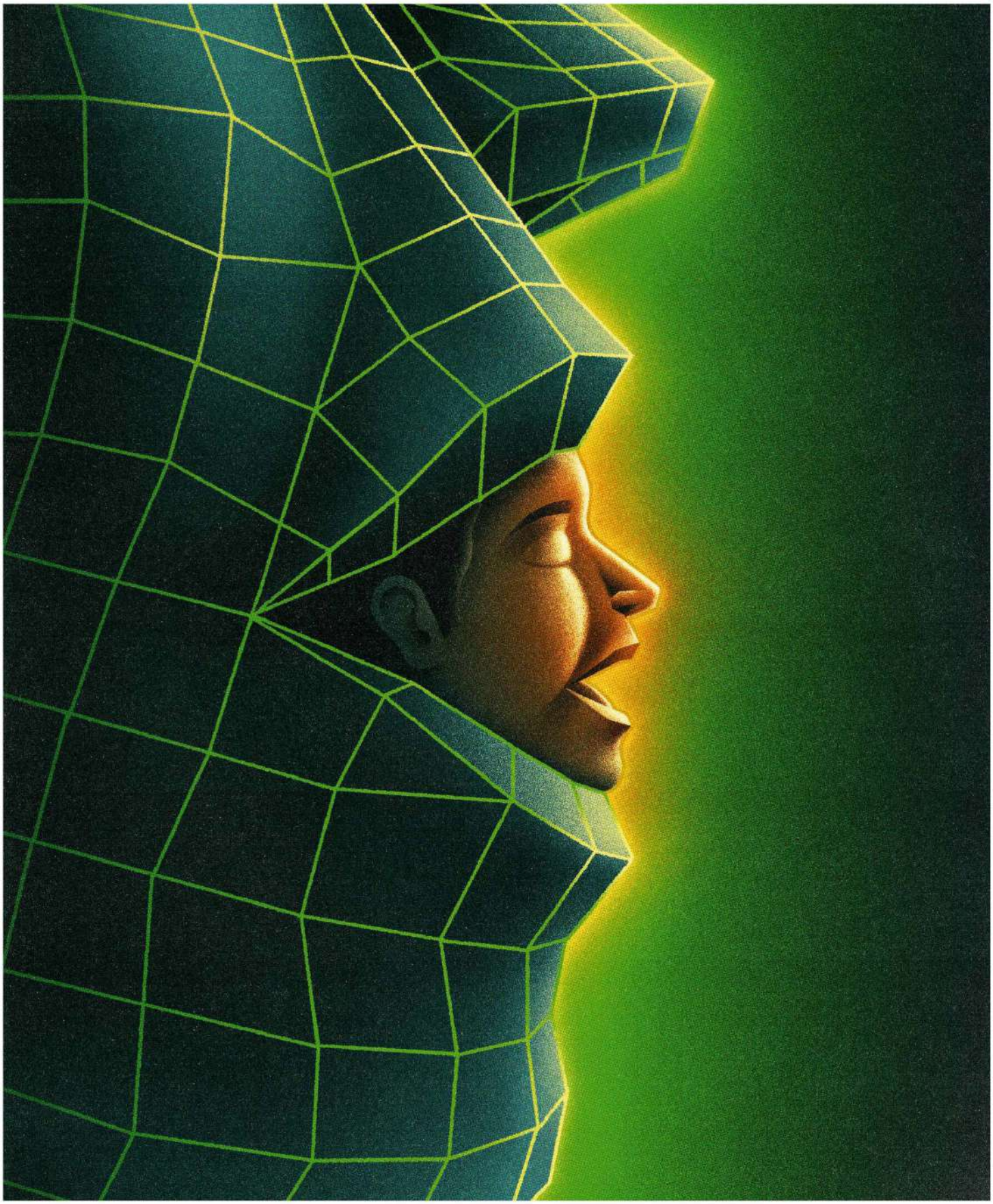


ILLUSTRATION: ADRIAN ARIAS ASTORGANO

COMMENT

AI-GENERATED EMAIL MAY BE CONVENIENT, BUT IT COULD KILL OFF ENDANGERED LANGUAGES

Bot-written text is already creeping into common use

In May 2023, Google unveiled a new, AI-powered tool called Help Me Write. Currently available in beta form, it automatically drafts email and form letters based on a user's simple instructions.

It promises to be a great boon for productivity, especially for those of us who loathe writing email. But the introduction of AI-generated communication may also be the death knell for endangered languages.

Thanks to the advanced capabilities of newer large language models, AI-authored text is about to be incorporated in most mass-market writing programs, from texting to email to general document generation.

Some of these platforms have incorporated AI in the past, for example to help make suggestions for how to finish a sentence. But AI is about to have a much larger hand in writing than ever before.

Currently, bot-written text can come across as a little hokey or generic-sounding (although ChatGPT does a pretty good job of composing sarcastic text messages to my friends). But it's already sophisticated enough for plenty of standard work email.

> "We may end up in a world where AI tools simply compose emails to each other"

It's also improving and, with enough training, an AI tool may even be able to learn individual preferences and write in a more personal style.

The prospects for business are obvious and the bots may help with more than just email laziness. AI-written text could be an equaliser, improving accessibility for people who have trouble writing appropriate prose, whether that's for disability, educational or other reasons.

And while we may end up in a world where AI tools simply compose emails to each other, I personally can't wait to leave most of my inbox to the machines.

But bot-composed text can also cause trouble. Language learning models have already created controversy by generating unexpected content, from inappropriate advice to harmful language, making clear the importance of careful editing and oversight.

Plus, the use of AI can be insensitive or rude in certain contexts. Earlier this year, Vanderbilt University administrators forgot to remove a 'written by AI' note from a condolence email they sent out after a school shooting, disgusting their student population.

A lesser talked-about concern is what AI-written text will do to language. I spent half of my life immersed in Swiss German, which is an umbrella term for a family of dialects spoken in the German part of Switzerland and some alpine towns in Italy.

Swiss German dialects are verbal languages with no universal spelling, but that hasn't stopped people from writing in them. And because the spelling is purely phonetic, each person's words tend to reflect their specific regional accent, as well as their personal quirks.

The introduction of spellcheck and autocorrect changed part of the communication among my Swiss friends. Suddenly, nearly every Swiss German word in our emails and text messages was incorrectly altered.

Many of us ended up disabling the correction tools in annoyance. But some people switched to official German. As AI-writing becomes common, there's no question that most of us will begin using formal German. Anything else would be too impractical.

AI-writing tools will be available in hundreds of languages. Google also has an AI-project called the 1,000 Languages Initiative, which it claims will support the thousand most-popular languages on Earth, including rare ones spoken by less than a million people. But it's not clear whether those efforts will translate to verbal languages, like the Swiss dialects. More generally, every edge case will probably conform to whatever formal words the AI has been trained on, causing us to lose some of the richness and diversity of human language.

And that's not all. AI is becoming incredibly adept at translating one language to another, which may soon reduce the need for human translators in publishing.

While this is an exciting development for some publishers, human translators have played an important role in oppressed countries by inserting political or other kinds of subversion into texts.

That's just one example of something that could get lost in AI-translation, and there's a lot more that we don't even know about.

When it comes to language, AI can only be trained on an existing body of vocabulary, meaning it can only look backwards. An AI tool may be able to combine words in creative ways or learn a style from past writing, but it won't naturally invent new slang and it'll always perpetuate the past into the future. We have no idea what this means for language development.

Amid larger concerns about the risks of AI, there are many smaller ripples like these; side effects that are difficult to anticipate. So, as we adopt AI-powered writing tools, it's worth thinking about how they'll impact both the conservation and the progress of language… and whether we care.

DR KATE DARLING
(@grok_)
Kate is a research scientist at the MIT Media Lab, studying human-robot interaction. Her book is The New Breed *(£20, Penguin).*

REALITY CHECK

THE SCIENCE BEHIND THE HEADLINES

Bugs on the brink | Killer asteroids | Ozempic

BBC SOUNDS

Discover how new insights into insects are helping us develop advanced robotics, new forensic techniques and more... in Metamorphosis

bit.ly/InsectInnovations

REVIEW

BUGS ON THE BRINK: WHERE HAVE ALL THE INSECTS GONE?

Noticed fewer bugs in your back yard lately? It's not just you. Insects around the globe may be dying out. And yes, it's our fault... but we also hold the keys to saving them

"One of the reasons [for decreasing insect populations] could be that plants exposed to more carbon dioxide have lower nutritional values"

BBC

Visit the BBC's Reality Check *website at* ***bit.ly/reality_check_*** *or follow them on Twitter* ***@BBCRealityCheck***

This year has seen a general sense of dismay spread across social media regarding the number of insects seen during the spring, with many naturalists and entomologists noting that there seem to be fewer around. So what's happening with insect life? Are there actually fewer bugs in our gardens? And what could this mean for the wider ecosystem?

WHAT'S THE CURRENT STATE OF INSECT LIFE?

The sad fact is that we simply don't know. We have a serious lack of data on long-term trends in insect populations worldwide. Given the huge number of species – possibly as many as 10 million – it's perhaps unsurprising. However, over the past few years, many studies have tended to point in the same general, downward direction. Of those insects we know much about, some are doing okay, but there are declines in well-known groups across the board, including butterflies, moths, dragonflies, some beetles and many bee species.

One survey that monitored insect splatter on car registration plates in Great Britain suggested that the number of flying insects has plunged by almost 60 per cent from 2004 to 2021.

IS THIS THE BEGINNING OF A LARGER-SCALE DECLINE?

Possibly. But we can't say this with any sense of certainty just yet. Many entomologists suggest that the very hot and dry summer last year may be affecting insects and this is certainly a good working hypothesis.

On the flip side though, others are reporting normal insect numbers in some parts of the country. To find out for certain what's happening this year we'll need to wait for the combined data from long-term studies.

What we do know is that we're still degrading the natural world in many places, sometimes seriously so. We can also say that, despite some improvements and success stories, the overall picture isn't positive whether we're looking at insects, mammals, birds, fish, plants or most other groups of living things. That said, we have proved to be very good at reversing declines when we want to. Tigers, for example, have rebounded in India and Nepal, doubling their numbers.

A big issue with insects is that people are much less likely to care about them than they are about big charismatic mammals like tigers.

WHAT'S CAUSING THE DECLINE?

Insects are extraordinarily diverse and live in a remarkable range of habitats. It's not surprising that there are different patterns, and different causes of those patterns, for various insect groups across the world. Nonetheless, we can make some generalisations.

Habitat loss and degradation as a result of human expansion and agricultural intensification are big players (water and soil pollution are important factors, and the use of pesticides can also impact some insects greatly).

Climate change can be more complex because some species can benefit from a warming climate and the rising levels of carbon dioxide in the atmosphere. But, on balance, it's looking like bad news for bugs.

One of the reasons could be that plants exposed to more carbon dioxide have lower nutritional values, which could harm insect diets. Worryingly, one 2021 US study concluded that the grasshopper population in Kansas was dropping two per cent each year due to starvation caused by climate change.

Some research also indicates that warmer weather could make plants simply less appealing to insects. For instance, one French study found rosemary plants that received 30 per cent less rainfall than normal emitted →

BELOW Pesticides used in industrial agriculture can have detrimental effects on insect populations besides the ones they're intended to kill

GETTY IMAGES X2

→ a subtle scent that actually deterred domesticated bees. But climate change or not, be in no doubt that whatever the causes of the decline, we're to blame.

WHY IS INSECT LIFE SO IMPORTANT?

Insects are like ecological glue, binding the natural world together. They're found in almost all terrestrial ecosystems and are involved in virtually every important ecological interaction. They're predators and prey, parasites, decomposers, nutrient cyclers, pollinators, seed dispersers, soil aerators and more.

When we start picking away at this ecological glue we risk damaging, or even destroying, the whole structure. In some cases, as with pollinators in some studies, we're seeing other species picking up the slack.

So, while we see a reduction in biodiversity, we don't always see a reduction in function. Just how long a system can tolerate this kind of pressure is unclear.

The notion that all insects will disappear is far-fetched. But the idea that we may end up with hugely depleted ecosystems that can't provide the 'services' we need – like pollination and nutrient cycling – seems far less far-fetched now than it did 20 years ago.

Over the coming years, it seems likely that we'll see many more negative effects. We'll be getting better at detecting them and we might, hopefully, also get better at combatting them.

IS THERE ANY WAY TO REVERSE THE DECLINE?

We can do things to slow down and even reverse the degradation of the natural world that we've caused. But it requires us to think in more mature ways than we're used to.

We often talk about 'saving' a species, or being concerned about a particular group (like insects). Such an approach is great for awareness and fundraising, but it doesn't fix the fundamental problem.

The reality is that we need to save their habitats – the places where nature can thrive. We also have to start thinking about the whole world as a habitat, not just the 'wild places' we see on nature documentaries.

Our towns and cities should be shared with biodiverse green spaces, interconnected with 'nature corridors' and dotted with ponds, tree stands and other features that support nature. Our agricultural practices need to change, allowing food production and nature to co-exist. We also need to make use of technological advances that allow us to produce more food from less land, giving more space for nature.

We can do these things, but we have to decide that we want to do them at a societal level. Up until now, we've been children in a sweetshop when it comes to using the planet. The declines we're seeing in the natural world are a sign that it's time to grow up.

by **PROF ADAM HART**
Adam is an entomologist at the University of Gloucestershire and presents shows on BBC Radio 4 and the BBC World Service.

ANALYSIS

KILLER ASTEROIDS: HOW SAFE ARE WE, REALLY?

A new study suggests we're safe from big impacts, but it's the small ones we have to worry about

It's the ultimate cosmic catastrophe. A killer space rock is locked on a collision course with Earth. When it hits, the curtain comes down on humanity as we fade into the shadows of history, just like the dinosaurs before us.

Despite being the subject of a string of apocalyptic Hollywood blockbusters, there is some good news. A recent study found that we're unlikely to be hit by any of the nearly 1,000 known near-Earth asteroids above a kilometre in diameter within the next millennium (the asteroid that unleashed hell upon Tyrannosaurus rex and co 66 million years ago is thought to have been between 10-15km – 6-9 miles – wide).

The study, led by Oscar Fuentes-Muñoz from the University of Colorado Boulder, is a marked improvement on previous work, which could only forecast a century ahead.

Although, according to Prof Phil Bland, an asteroid expert at Curtin University in Australia, the '1,000 impact-free years' claim comes with some important caveats. Most notably, it only applies to the big asteroids we already know about.

"It doesn't speak to the five per cent that are still out there waiting to be discovered," he says. "It doesn't include comets either, which we'll never be able to constrain."

This could be important, as many comets, which can be as big as asteroids, fly in from the outer Solar System having never entered the inner Solar System before. We have no way of tracking them until they're already very close to us.

Then there are all the asteroids smaller than a kilometre (just over half a mile) across. "We're not good at all at tracking smaller stuff," Bland says.

After all, the sky is an incredibly big place and these objects are relatively small. It's like looking for a tiny, dim needle in an unimaginably large, even darker haystack. For example, some asteroids reflect just five per cent of the sunlight that hits them.

To underscore the potential for a surprise impact, consider the 70m-wide asteroid 2023 DZ2 that passed between Earth and the Moon back in March. Astronomers only spotted it a month beforehand.

Had it hit Earth, it could have levelled a city. This

SHUTTERSTOCK

"The '1,000 impact-free years' claim comes with some important caveats. Most notably, it only applies to the big asteroids we already know about"

close call came just two months after a truck-sized asteroid dubbed 2023 BU came within 3,600km (2,230 miles) of the southern tip of South America. That's 10 times closer than some of our communications satellites. It was discovered less than a week before it narrowly missed by us.

Such asteroids don't even have to strike the planet's surface to inflict significant harm. "Objects as small as 50m can cause an airburst [mid-air explosion] that's really devastating over a local area," Bland says.

In February 2013 a 15-20m object exploded in the atmosphere above Chelyabinsk in Russia. Almost 1,500 people were injured and more than 7,000 buildings damaged. The total cost of repairs came to around £26 million.

ABOVE Although no bigger than 20m, the meteorite that exploded over Chelyabinsk, Russia, in 2013 caused widespread injury and damage

Since then, astronomers have been ramping up their search efforts accordingly. Last year the NASA-funded Asteroid Terrestrial-impact Last Alert System (ATLAS) project became the first survey capable of searching the entire dark sky every 24 hours for near-Earth objects (NEOs) that could pose a future impact hazard to Earth. The Vera C Rubin Observatory in Chile →

ABOVE A fragment of the approximately 20m-wide meteorite that exploded above the Russian city of Chelyabinsk in 2013

→ also reached a significant construction milestone in May this year with the completion of the telescope structure. It's now ready to be integrated with the telescope's 3,200-megapixel camera, the largest digital camera ever built, and eventually form the LSST (Large Synoptic Survey Telescope).

Astronomers hope to start using the LSST to survey the sky in October 2024. "It'll give us a really interesting new look at this population of small asteroids," Bland says

Slightly further down the line, NASA hopes to launch its NEO Surveyor satellite in 2028. It should discover tens of thousands of new NEOs with diameters as small as 30m.

So, what happens if one of these projects detects an asteroid on course for a direct hit? "Asteroid impacts are one of the few natural disasters that can be prevented through human action," note Fuentes-Muñoz and his colleagues in their study.

NASA registered a significant breakthrough in 2022 when its Double Asteroid Redirection Test (DART) mission slammed a fridge-sized impactor into the asteroid Dimorphos.

The collision successfully altered Dimorphos's orbit around a second asteroid called Didymos by 32 minutes. A triumph given that NASA's threshold for success was set at just 73 seconds. Perhaps in future we could knock a threatening asteroid off course in a similar manner.

At the time, NASA's Administrator Bill Nelson said that the success of DART "shows that NASA is trying to be ready for whatever the Universe throws at us." Completing a catalogue of smaller potential threats would be an equally big step in the right direction.

by **COLIN STUART** *(@skyponderer)*
Colin is an award-winning astronomy writer and speaker.

COMMENT

OZEMPIC: IS IT MORE THAN JUST A WEIGHT-LOSS PILL?

The diabetes drug is useful in treating obesity, but could also help with a range of other conditions

Semaglutide – most often known by the brand name Ozempic, but also sold as Wegovy and Rybelsus – was developed to treat type 2 diabetes, but has been making headlines as a weight-loss drug. Now, with prescriptions for ozempic increasing, reports of other potential benefits are emerging, from reducing addictive behaviours to improving mood and brain function. Are there more uses for Ozempic?

Ozempic mimics the biological actions of a naturally produced hormone called GLP-1 (glucagon-like peptide-1). GLP-1 is one of the major hormones secreted by the gut after eating. It forms part of the complex pathways that signal to the rest of the body that food has been eaten. These pathways prevent over-consumption by signalling satiety – the feeling of satisfaction that comes after eating – and trigger the biological pathways that allow the body to use the nutrients that come from food. This includes increasing the production of insulin, which is important in moving sugar (glucose) from the blood into cells so that it can be used as energy.

By enhancing the promotion of insulin secretion, Ozempic and other GLP-1-mimicking drugs can help treat type 2 diabetes and suppress appetite, which can support the treatment of obesity. Ozempic is about 95 per cent similar to natural GLP-1, but the small differences make it easier for it to bind to carriers in the blood and harder for it to be broken down. So instead of peaking then rapidly dipping after a meal, as natural GLP-1 does, it can stay in the system longer, have larger impacts and reach other organs more readily.

Recently, reports have emerged of other potential off-target, but positive effects. Examples include reported reductions in alcohol consumption, smoking and nail-biting, as well as improvements in anxiety, stress and depression. A Danish study following users of semaglutide or liraglutide (another similar drug) for five years found that users had a lower incidence of dementia. These anecdotes and observations raise the possibility that Ozempic could be repurposed to fight other difficult-to-treat conditions.

This isn't a new concept – drugs are often repurposed, or repositioned, from their original uses. A well-

SHUTTERSTOCK, SCIENCE PHOTO LIBRARY

"By mimicking the actions of GLP-1, Ozempic could have positive effects on cravings and brain health"

ABOVE Ozempic, illustrated here in its molecular form, mimics the effects of GLP-1, a hormone that helps regulate food intake

known example is sildenafil, marketed as Viagra. Now famous as a treatment for erectile dysfunction, it was originally researched and designed as a treatment for high blood pressure and angina pectoris (a cardiovascular disease). An earlier example is aspirin, or acetylsalicylic acid: originally marketed over 100 years ago as an analgesic, it was later discovered to be an anti-inflammatory. Identifying specific effects for aspirin in reducing platelet aggregation when given in low doses led to a new use in preventing risk for certain cardiovascular diseases.

It's biologically plausible that, by mimicking the actions of GLP-1, Ozempic could have positive effects on cravings and brain health. When natural GLP-1 is released from the gut, the majority of its appetite-suppressing effects occur through influencing the gastrointestinal tract. But GLP-1 isn't just released in the gut in response to eating: it's released by other cells, including neuronal cells. In the brain, GLP-1 has been shown to interact with reward pathways, potentially altering our responses to food, alcohol and drugs.

While Ozempic may be given for pancreatic and appetite impacts in the treatment of diabetes and obesity, because it's more stable Ozempic can travel widely through the body, including crossing into the brain, where it can reach additional receptors. In the brain, GLP-1 and its mimetics may also influence neuroinflammation (inflammation in the brain), which may protect against degenerative conditions such as dementia and Alzheimer's disease.

Any reduction in alcohol consumption may also be linked to changes in appetite. How alcohol affects us, including how quickly it's absorbed and what side effects we feel, changes depending on how much we've eaten. The reduced calorie intakes that follow Ozempic-induced satiety might result in changes in drinking experiences and therefore reduce its appeal.

The mood-based changes may also be explained by indirect effects. Weight stigma is linked to poorer mental health, so it's unsurprising that Ozempic users experiencing weight loss may experience improved mood. Weight loss is also related to feelings of self-efficacy, the confidence a person has in their ability to engage in a particular behaviour, so Ozempic might be acting as a kick-start to feelings of control.

More research is needed into these possibilities, and into the possible negative side effects, before recommendations can be made for repositioning Ozempic as a medication for addiction, mental health or neurodegenerative conditions.

The drug's negative side effects can include nausea, diarrhoea, vomiting, constipation, thyroid tumours, pancreatitis, and kidney and gallbladder problems. These need to be weighed against the potential benefits when making decisions around Ozempic, regardless of the anecdotes and media frenzy. **SF**

by **DR EMMA BECKETT**

Emma is a senior lecturer in the School of Environmental & Life Sciences at the University of Newcastle (Central Coast) and senior food & nutrition scientist at Nutrition Research Australia.

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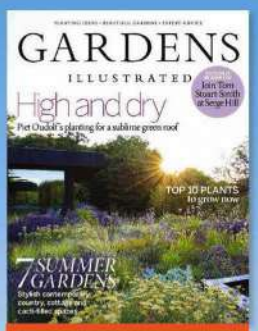

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INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

INTERVIEW

APPLE'S ATTEMPT AT VR

A virtual reality expert analyses Apple's recently announced VR headset **p42**

REVIEW

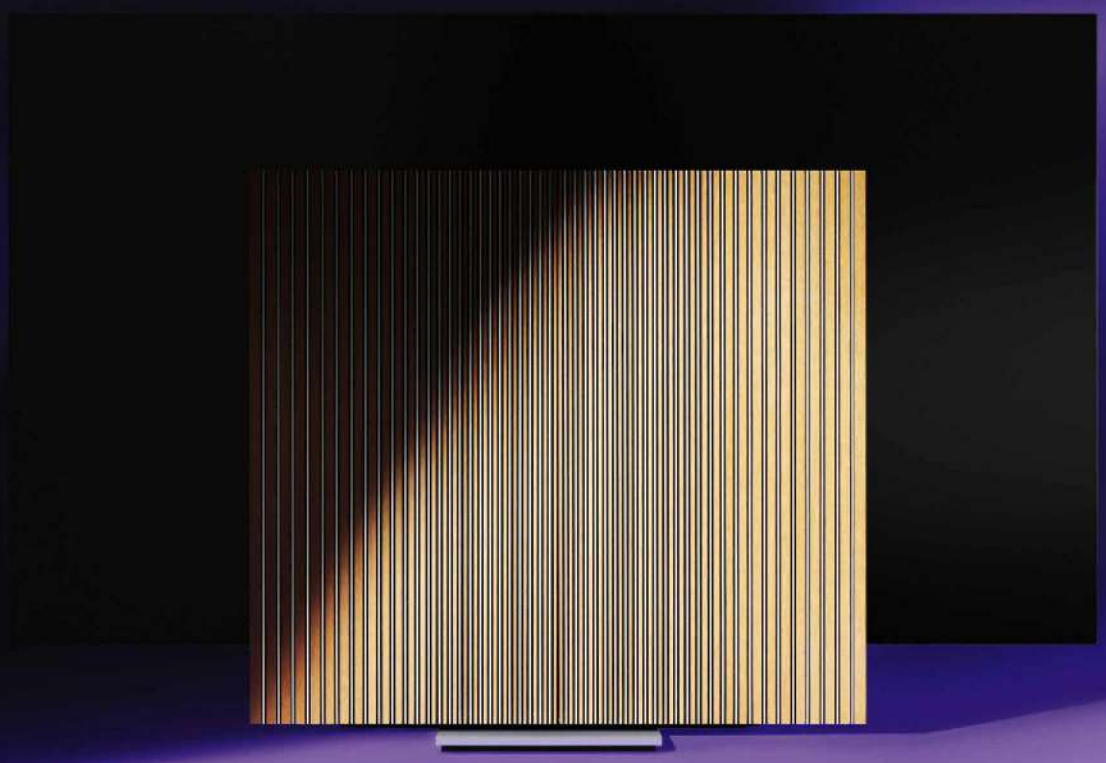
HAND-HELD VACUUM CLEANERS

Five devices that all totally suck... just not in a bad way **p44**

NEW TECH

IDEAS WE LIKE

This month's pick of the latest and greatest gadgets **p46**



B&O is on a mission to bring you the biggest OLED TV... assuming you can fit it in your living room **p46**

171m THE NUMBER OF PEOPLE THAT USE VR TODAY

1 IN 3 PEOPLE EXPERIENCES MOTION SICKNESS WHILE USING VR

$296 bn

THE VALUE THE VR MARKET IS EXPECTED TO HIT IN 2024

INTERVIEW

Apple Vision Pro: a virtual reality expert gives his verdict

David Reid, a professor of AI and spatial computing, explains why Apple is leading the way when it comes to virtual reality

Apple isn't exactly known for being the pioneer of new technology. Whether it's smartphones, music players or computers, Apple is rarely first out of the gate.

Instead, it waits. A few years go by, technology advances and after its competitors have released a few versions of their devices, Apple swoops in with its first iteration of the technology – one that's refined, powerful, stylish and always extremely expensive.

Years on from the initial boom of virtual reality, Apple has finally played its card, unveiling its first virtual reality headset. It might be late to the party, but Apple has made its usual move, with its first ever step into virtual reality being the best model we've seen yet.

But what's so good about Apple's first venture into the world of the virtual? We spoke to David Reid, professor of AI and spatial computing at Liverpool Hope University to find out.

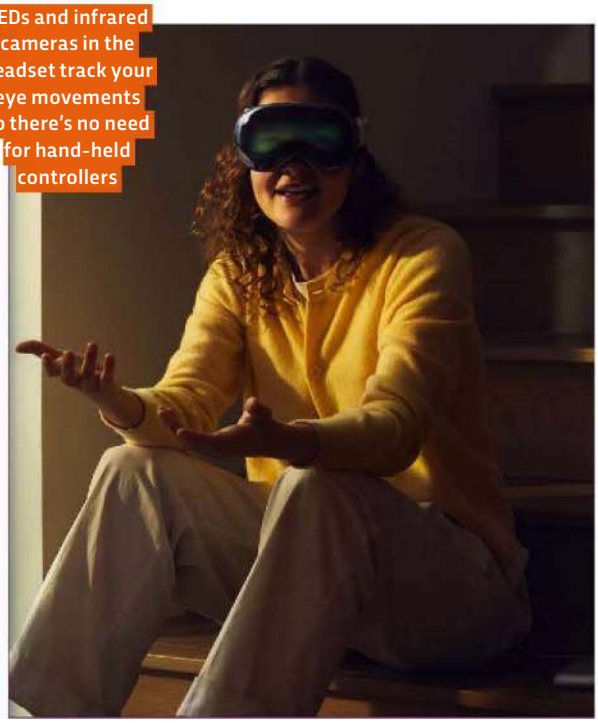
BLENDING REALITIES

Unlike some previous attempts at virtual reality headsets, Apple's Vision Pro device uses a mixed-reality format. This means that, instead of blacking out the world around you, the headset mixes the virtual world with the real one.

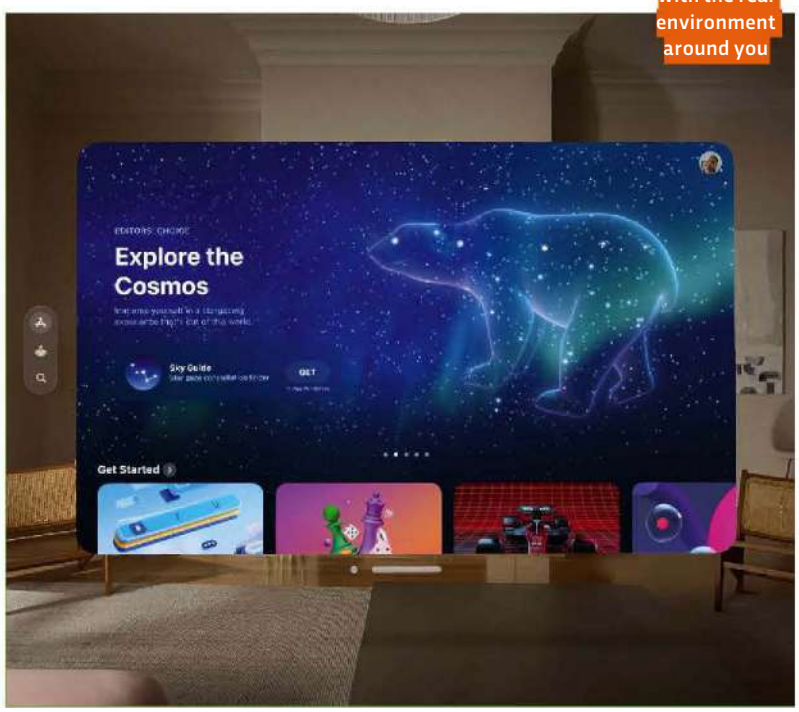
Put the headset on and you could interact with a virtual floating monitor above your desk, play games in your living room or essentially make the real world that little bit more fun.

"The big selling point here is that Apple is trying to expand what we mean by the metaverse. Where Meta is based in virtual reality, Apple is looking at augmented reality, putting these virtual elements into the world around you," says Reid.

"There is a theory known as spatial computing. It's the idea that a machine can retain and manipulate referents to real objects in the world. That's what Apple is doing here and doing so believably."



LEDs and infrared cameras in the headset track your eye movements so there's no need for hand-held controllers



The mixed-reality format blends virtual elements with the real environment around you

Apple's Vision Pro headset is expected to be released in the US early in 2024

This doesn't mean that the headset is incapable of using virtual reality. With a toggle of a switch on the side of the headset, users can alter how much of the world around them is blocked out.

Able to access both virtual and mixed realities, Apple is looking to offer the best of both worlds. While it isn't the first to do this, Apple is the first to do it with this much processing power.

POWER ON TOP OF POWER

Where Apple really stands out from the crowd is inside the headset. Apple uses two separate chipsets with the Vision Pro: one for processing graphics, vision algorithms and running the software; and a second focused exclusively on processing input from the cameras, sensors and microphones.

This dual setup allows images to be displayed lag-free in 12 milliseconds. In theory, this results in a far smoother virtual reality experience, free of jolty movements taking you out of the experience.

"Essentially, this is more powerful than a Macbook Pro. It's basically a computer strapped to your face. I'm sure this will mean lots of new applications and new ways to not just play games, but to work, socialise and even just browse the internet," says Reid.

"You'll be able to do things as creatives and professionals that you can't do on conventual computers. Because of the price, it'll only be early adopters using it to begin with, but as it gets cheaper and more readily available, Apple will be leading the way for virtual reality."

Along with the powerful processors, Apple has introduced a number of other unique features. Controllers are gone and in their place are powerful eye trackers that can precisely determine what you're looking at.

APPLE X3

There are 12 cameras and five sensors in the headset. These monitor hand gestures and map the external environment. Two of these cameras transmit roughly a billion pixels per second to the display, depicting the real world around the user.

As an additional level of immersion, Apple has input speakers on either side of the headset. These speakers feature dual-driver audio pods positioned right next to the ears. They analyse a room's acoustic properties, adapting the sound to match the space.

"The headset has over a dozen cameras and a complicated tracking system. That requires a huge amount of processing power, but Apple has managed to implement that. That would be impressive enough, but Apple then added in a whole host of other high-end features on top," says Reid.

THE MOTION SICKNESS PROBLEM

Throughout all versions of virtual reality, there is one major problem that has plagued the technology: motion sickness. Unsurprisingly, two tiny screens inches from your eyes showing rapidly moving footage has the tendency to make people feel a bit sick.

So, has Apple found a solution to this problem? Kind of. "It's better, but it still isn't ideal. The main problem with virtual reality motion sickness is vergence-accommodation conflict (VAC)."

VAC is, in essence, an issue that we experience when the brain receives mismatching cues between the distance of a virtual 3D object and the focusing distance required for the eyes to focus on that object.

This frequently occurs with virtual reality due to the nearness of the display. Currently, there's no fix for this with virtual reality, but a number of companies (including Apple) are working on technology that could solve the issue.

"ESSENTIALLY, THIS IS MORE POWERFUL THAN A MACBOOK PRO. IT'S BASICALLY A COMPUTER STRAPPED TO YOUR FACE"

"Apple has tried to reduce the motion sickness as much as possible. By reducing lag and delay, and using high-quality displays, Apple has made a headset that is best in class in terms of motion sickness," says Reid.

Motion sickness is still going to occur and, for some, it's always going to be a problem when interacting with virtual reality. However, Apple seems to be ahead of the game at minimalising the problem as much as possible.

Five of the best hand-held vacuum cleaners

Keep your house clean and tidy with these light and portable vacuum cleaners. The *BBC Science Focus* team picks its favourites

Gtech Multi MK2

gtech.co.uk, £169.99

Don't be thrown off by its size: the Gtech Multi Mk2 is a powerful piece of kit. It can remove entrenched hair from a carpet, whisk away dust piles stuck in hard-to-reach areas, and do everything in-between.

Gtech has included some clever tricks, such as scented sticks that pump pleasant aromas into the air, and a plethora of attachments to reach into every crevice and space. The Multi Mk2 doesn't have the greatest battery life out there at 30 minutes, or some of the fancier features that other hand-held vacuums do, but with a price tag at the lower end of the market, it's hard to argue against the value it offers.

BEST VALUE FOR MONEY

BEST FOR PET OWNERS

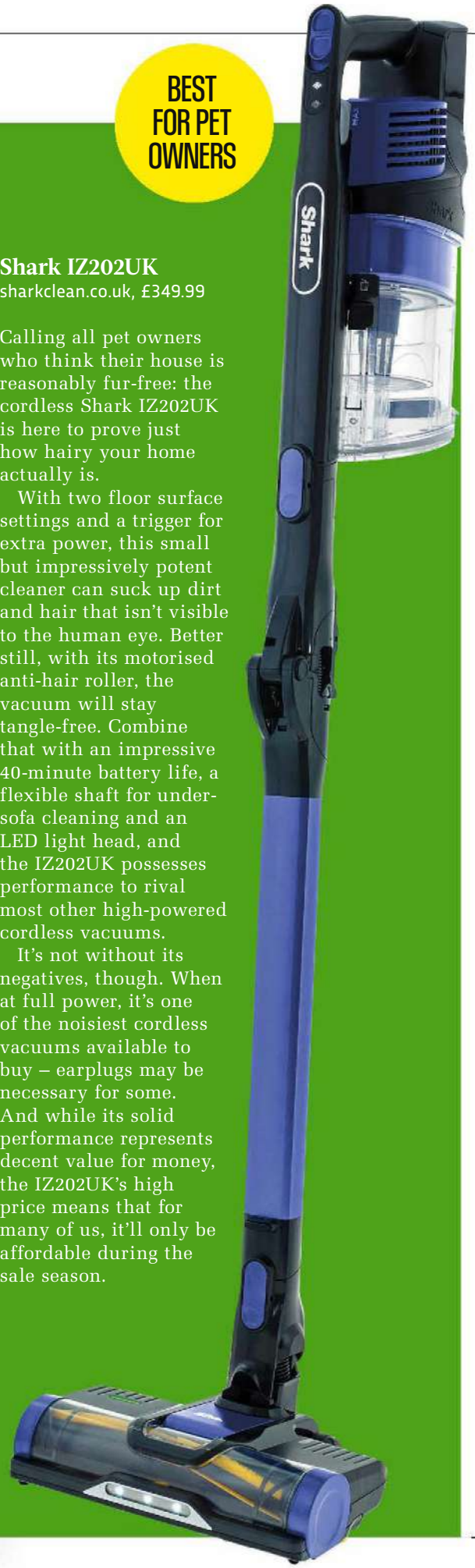
Shark IZ202UK

sharkclean.co.uk, £349.99

Calling all pet owners who think their house is reasonably fur-free: the cordless Shark IZ202UK is here to prove just how hairy your home actually is.

With two floor surface settings and a trigger for extra power, this small but impressively potent cleaner can suck up dirt and hair that isn't visible to the human eye. Better still, with its motorised anti-hair roller, the vacuum will stay tangle-free. Combine that with an impressive 40-minute battery life, a flexible shaft for under-sofa cleaning and an LED light head, and the IZ202UK possesses performance to rival most other high-powered cordless vacuums.

It's not without its negatives, though. When at full power, it's one of the noisiest cordless vacuums available to buy – earplugs may be necessary for some. And while its solid performance represents decent value for money, the IZ202UK's high price means that for many of us, it'll only be affordable during the sale season.



BEST FOR QUICK CLEANING

Bosch Unlimited 7

bosch-home.co.uk, £299.99

After you've used it a few times, the Bosch Unlimited 7 starts to feel like an extension of your arm. A slight lean one way and you can scoot around a corner – useful if you don't fancy the cardio workout that pushing a vacuum around the room often entails!

It's intuitive, easy to handle and comes with a few nifty features, such as a swappable battery that's compatible with Bosch's other gardening and power tools, and a tube that bends through 90° and pops back into place with a satisfying click. It's lightweight, too, although that does come at the cost of a reduced capacity dust bin, with room for just 0.3l of dust and dirt.

Battery life is impressive – if you're using the eco setting. For hard floors, lino and office-style carpets, eco mode will see you get a cool 40 minutes of use from this vacuum. But for stubborn, trodden-in dirt, thick carpets or deep grooves, you'll need the more power-hungry turbo mode.

Tower T527000

towerhousewares.co.uk, £49.99

A tower not in size but in name, shape and value for money, the T527000 is a handy little dust-buster that won't break the bank.

The Tower excels when it comes to small jobs like tackling cobwebs, piles of breadcrumbs and dirt (though one of its fittings can do no such thing) and sand in your car's footwells, but don't expect to be able to vacuum your whole house with it.

BEST FOR SMALL JOBS

Even if you were patient enough to try (its small size is great for tight spaces but not for bigger areas), its limited battery life and dust capacity would probably stop you pretty soon.

The Tower is also great for those occasions when you need to clean it, as the device is easily dismantled thanks to its quick-release buttons. At under £50, the Tower represents good bang for your buck.

Dyson V12 Detect Slim Extra

dyson.co.uk, £529.99

This is a vacuum cleaner with fricking laser beams. No, really – you can now get Dyson cleaners with a head that scatters green light across hard floors (doesn't work with carpets) to show you just how dirty they are.

The light shows up all kinds of dust, hair and debris giving you gratifying feedback as you go. It turns cleaning up into a game and, before you know it, you'll find yourself speeding around the home gobbling up dust like Pac-Man.

For those with carpets, the V12 does a good job thanks to it various attachments. Dyson's smallest device works best as a second cleaner for the home, as the battery won't last for much more than a couple of rooms and it needs frequent emptying.

BEST FOR MAKING CLEANING FUN

Ideas we like...

Our pick of the month's smartest tech

↑ ...A TV too big for the home

Not every new product has to be practical, or even worth buying – sometimes it's just fun to push boundaries and see what's possible. That's what has happened with B&O's latest television, which costs an unbelievable £50,650. We all know that's far too much money for a TV, but there's a reason for the price. This is a 97in TV, making it the largest OLED set on the market. To get the full value for the life savings you've poured into this, there are also motorised unfolding speakers and a stylish oak stand.

B&O Beovision Harmony
£50,650, bang-olufsen.com

...A camera built for vloggers

Vlogging cameras were made somewhat obsolete by smartphones, but they're making a comeback. Canon's PowerShot V10 is a highly portable cam that fits in the palm of your hand, yet boasts a built-in pop-up screen, two stereo mics and a stand. A lot of work has also gone into the software, with adjustable filters, subject detection for adjusted lighting and a wide-angle lens option. At £429.99, though, it's one for serious vloggers only.

PowerShot V10
£429.99, Canon.co.uk

...The cooler-powerbank combi

A cooler with built-in powerbank may not be an essential purchase, but it's a gift any tech-obsessed camper will fall in love with. Anker's EverFrost can keep food and drink cool without ice for up to 42 hours, and handily features separate freezer and fridge compartments. The solar panel and power bank, meanwhile, will keep all your other gadgets ticking over, refuelling your smartphone up to 19 times from a single charge.

Everfrost Powered Cooler
£TBC, Anker.com

...High-tech swimming goggles

It doesn't matter how they're designed, swimming goggles are never flattering, so you might as well get maximum performance out of them. Aquasphere's Defy Ultra goggles offer panoramic vision both laterally and vertically, giving you a full view of your underwater surroundings, while the ultra-light frame reduces water drag. There's even a quick-fit buckle and quick-drying design – all useful stuff for serious swimmers.

Aquasphere Defy Ultra
£90, uk.aquaspherewswim.com

...Revolutionising video calls

The days of blurry video and static-crackled voices may soon be over. 'Project Starline' combines spatial audio, machine learning and real-time compression to create what Google claims is a convincing, photorealistic model of the person you're speaking to. It's not yet available to the masses, but if it works, this could be the revolution video calling has been waiting for – albeit a large, complicated and expensive one.

Google Project Starline
£TBC, Ai.Googleblog.com

IDEAS WE DON'T LIKE...

...A FREE TV WITH A HUGE CATCH

Do you want a TV for free? No, really – a completely free TV! All you have to do is watch adverts... all the time. The company behind the deal, creatively known as 'Telly', is giving away thousands of 55in 4K HDR TVs, with an attached soundbar. All sounds good so far? Well, the part that keeps it free is a hefty 9in screen attached below that plays adverts 24/7. You also have to agree to hand unspecified data over to the company. With concerns already being raised about its terms and conditions, this free TV could be your passport to a whole truckload of data harvesting. We'll pass.

Free Telly
£0, freetelly.com

...AN OVERPRICED SCREEN FOR YOUR NFTS

NFTs have pretty much died a death now. The collections of apes and other doodles that celebrities once held so dear may have fallen sharply in value, but that hasn't stopped Danvas releasing the Series G, which is described as "the first luxury digital display". The Series G is, in essence, a $34,000 (£27,350), 1.2 x 1.2m TV on which to show off your NFT collection – but if that seems steep, then you'll be glad to hear that installation is a snip at just $2,500 (£2,010)!

The good news is that with plummeting NFT costs, the artwork that appears on the screen has never been cheaper...

Danvas Series G
$34,000, Danvas.art

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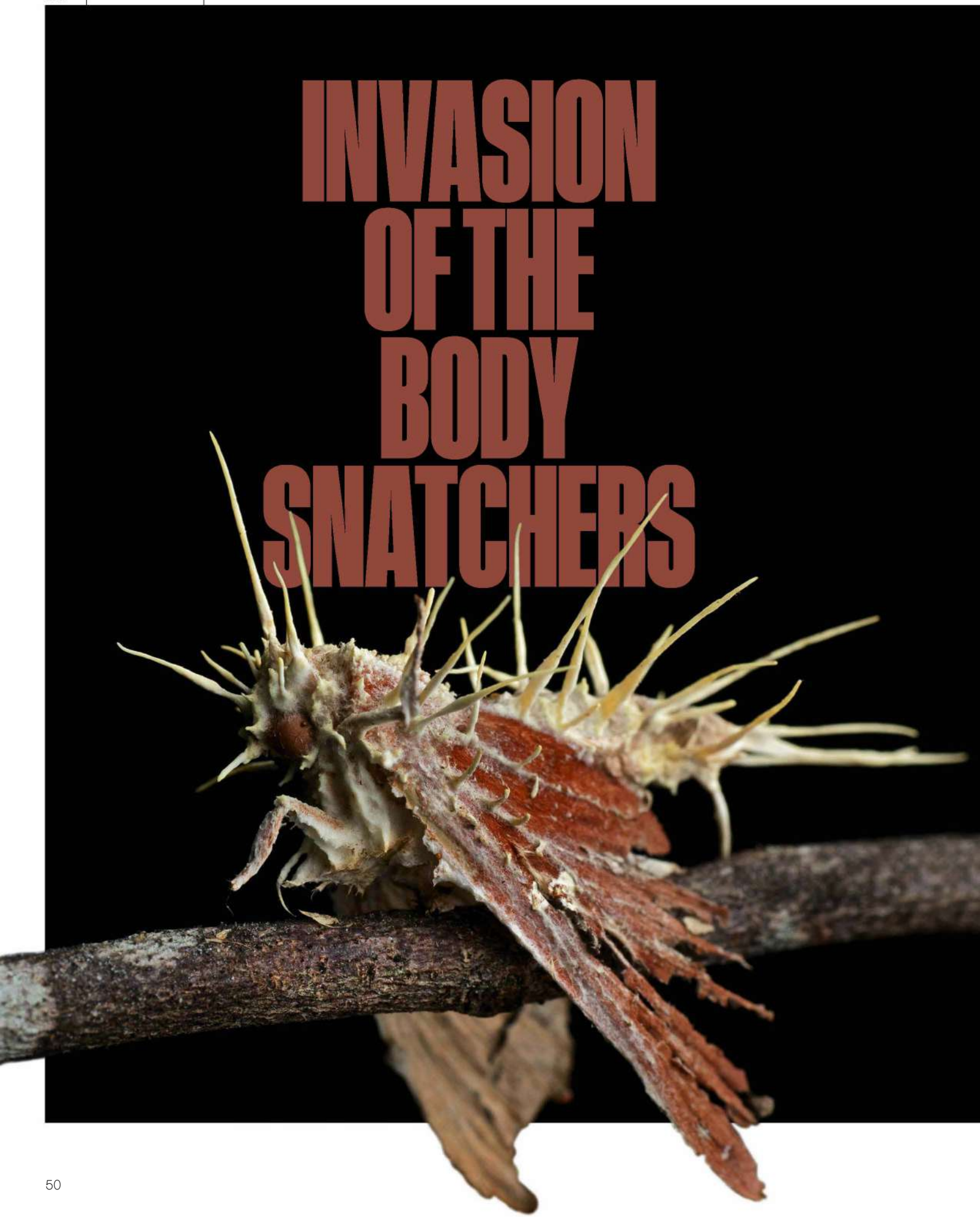
INVASION OF THE BODY SNATCHERS



The hit TV show *The Last of Us* imagined an apocalypse caused by a *Cordyceps* fungus turning humans into zombies. For many insects, real life isn't much different...

by **PROF ADAM HART**

When we think about living things and where we find them, we tend to think at large scale. The word that comes to mind is 'habitat', which conjures up images of forests, deserts, oceans, swamps and the many other diverse places on Earth where life can be found. Of course, we might also be thinking at a smaller scale, focusing perhaps on our garden, a local hedgerow or a small pond.

If you think at the right scale, though, pretty much any physical space can be habitat to something. Anyone who has looked closely at mites living on a leaf, or at tiny springtails under the decaying bark of a dead tree, will have marvelled at the wonder of microhabitats. But when you start thinking at a really small scale, when a microscope is needed to see what's going on, then habitat can become very interesting indeed – because once you think small enough, there's no better habitat than that offered by other organisms.

Living in or on other organisms offers many advantages – if you can pull it off. Your host may not be entirely amenable to you taking up residence, but they can provide you with all the shelter, resources and travel you might require. You may even provide your host with some advantages in return: many of the bacteria that live within our guts, for example, help us with aspects of digestion. Such mutually beneficial relationships are known as mutualisms, and are quite common.

But not every organism that lives in or on another organism brings benefits – sometimes, these passengers can cause harm. When an organism is harmful to its host, we call it a parasite.

Interactions between hosts and their parasites can be some of the most fascinating, and sometimes disturbing, in the entire natural world. Many of the more bizarre interactions have evolved because it's advantageous for the parasite to control its host, causing it to behave in odd ways that benefit the parasite. In some cases, parasites can literally take over their host.

The images in this feature reveal the rather grim aftermath of successful parasite takeovers. Some have reduced their hosts to a 'zombie' state, while other hosts face a quicker and simpler fate: simply being overwhelmed by their alien invaders.

FUNGAL INVASION

Insects, spiders and other invertebrates are affected by a whole range of parasites. The organisms that you can see growing out →

"Sometimes, these passengers can cause harm. When an organism is harmful to its host, we call it a parasite"

ABOVE
Ophiocordyceps dipterigena sprouting out of an Indonesian robber fly

OPPOSITE
Infection by an *Akanthomyces* fungus, part of the *Cordyceps* family, leaves this moth looking nothing like its former self

PAUL BERTNER/MINDEN PICTURES, CHIEN LEE/MINDEN PICTURES

MORLEY READ/NATUREPL.COM, PAUL BERTNER/MINDEN PICTURES X2

→ of the bodies of the unfortunate creatures here are parasitic fungi. In all cases, the fungus has infected, and then taken over, the body of the host.

The initial stages of infection are straightforward. Spores from a parent fungus are tiny and easily transmitted through the air or on surfaces. Insects are very good at grooming themselves and, in the case of social insects, such as ants, each other. Many insects have special adaptations to their legs or mouthparts that make grooming more effective, enabling them to remove spores and other undesirables to prevent infection. But no matter how scrupulous insects are with their hygiene, sometimes they miss something.

Fungal spores left unchecked by grooming can start to develop, or germinate, on the surface of an insect. The first challenge facing the fungus is finding a way to drill down through the tough chitin that forms the insect's exoskeleton. To do this, the spore forms a sticky 'holdfast' structure that firmly attaches it to its host and provides a stable drilling platform. Once stuck in place, this structure produces a cocktail of enzymes that allow the developing fungal strands, or hyphae, to punch their way through the exoskeleton into the nutrient-rich environment of the insect's insides.

Once through the exoskeleton, the fungus is able to feed on the living structures of the host. Fungi can grow rapidly and when the invading parasite has become sufficiently large, two things occur.

The first is that the insect dies: there is, after all, only so much insect biomass that can be converted into fungal biomass before the insect ceases to function. The second thing that occurs is that the fungus reproduces. The structures you see coming out of the bodies of the insects and spiders in the photographs here are the fruiting bodies of the infecting fungi. Akin to mushrooms, these structures produce the spores that can go on to infect future hosts.

SPREADING SPORES

Natural selection has favoured fungi that are better able to infect the next generation of unfortunate hosts. One way to do this is to produce many spores. There is a limit to how many spores can be produced, though, because the fungus only has the nutrients supplied by a single, generally quite small host. Another option is to find ways to spread spores more effectively. A good way to do that is to get the spores up high, into a breeze that can carry them further afield, but for a fungus inside an insect host on the forest floor, that's not so easy. Fruiting bodies can be made longer, an adaptation you can see in many of these images, but there's a limit to that due to the trade-off between making more spores and making longer structures from which to broadcast them.

Fungi have other problems, too. Sometimes the environment in which insects live is not favourable to fungal growth. Ant nests, for example, may not have the right temperature or humidity. →

CLOCKWISE FROM ABOVE A *Cordyceps* fungus hijacks a spider in Ecuador; an ant in Vietnam infected by *Stilbella buquetii*, AKA the gill mushroom; a spider seize by *Torrubiella*, another type of *Cordyceps*

×

“Once through the exoskeleton, the fungus is able to feed on the living structures of the host”

→ If only there was a way of moving to a better location – perhaps getting higher and saving resources for more spore production.

Some fungi, once they have made it into the body of their host, are able to manipulate its behaviour to get them to exactly where conditions are right for the fungus. There are at least two groups of fungi that can turn their hosts into such fungal-controlled 'zombies': *Cordyceps* and *Ophiocordyceps*.

I saw my first zombie ant when I was doing field work in Panama. Once I got my eye in, they become a common sight because all the infected ants had the same odd appearance. They were all firmly

ABOVE This Madagascan dragonfly has become infected by the *Ophiocordyceps odonatae* fungus, with deadly results

LEFT Beneath this seething mass of *Ophiocordycipitaceae* fungus is what used to be a healthy wasp

RIGHT Not all fungal parasites infect insects – some attack other fungi. This is a mushroom that has been overtaken by the *Spinellus fusiger* fungus, whose filament-like hyphae are commonly known as 'bonnet mould'

> "The insect dies and the fungus reproduces, sending out spores to start a new generation"

MINDEN PICTURES X2, DAVE PRESSLAND/FLPA/MINDEN PICTURES

clamped onto plant stems with their jaws, a short distance above the ground. In most cases, but I suspect not all, the ants were dead. The ant bodies stuck out horizontally from the plant stem, with fungal growth and fruiting bodies clearly visible. Looking like little flags, perhaps a better way to describe them would be 'spore salt-shakers', since the fruiting bodies being held aloft were broadcasting spores across the forest.

The reason these ants climbed to their final resting place to clamp onto a stem and await death is that the fungus was able to exert chemical control over their nervous systems. The infected species of ants usually live in the forest canopy, but when infected they start to convulse, causing them to fall to the forest floor. Once there, the host then finds a plant stem and begins to climb to a height of 25-30cm. It's there that the final flourish of behavioural control occurs – the ant clamps its jaws onto the stem. The insect dies and the fungus reproduces, sending out spores to start a new generation.

NATURAL BORN KILLERS

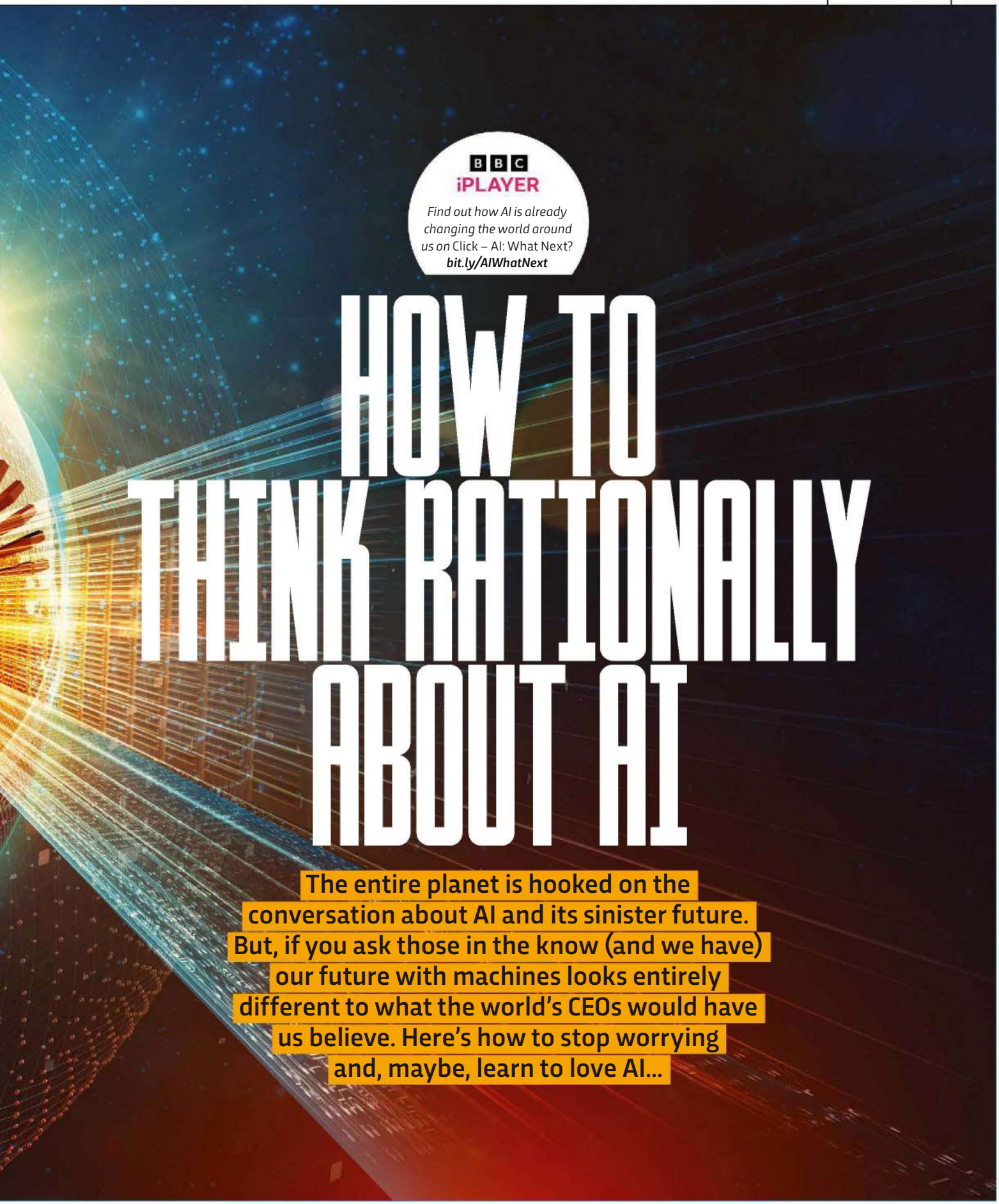
There are many other species of fungi that are 'entomopathogenic' – that is, they cause serious disease and often death in insects. One common type is *Metarhizium*, a group consisting of more than 50 identified species that can infect a wide range of insect hosts. We can make use of these fungi's incredible efficiency in pest control. Some species are now used to control insect pests, giving us the option for more environmentally sympathetic biocontrol compared to using chemical pesticides.

Fungi tend to be overlooked when we think about biodiversity, but we really should give them more attention and pay them far more respect. They are crucial to ecosystem functioning and, as decomposers, they are the interface between life and death. Whether recycling waste, enhancing plant growth, controlling potential pests or hijacking insect nervous systems, there's much we can learn from them. SF

by **PROF ADAM HART**

Adam is an entomologist at the University of Gloucestershire and can be heard regularly on BBC Radio 4. He co-presented the BBC TV series Planet Ant *and* Hive Alive.

ILLUSTRATION: ANDY POTTS



BBC iPLAYER

Find out how AI is already changing the world around us on Click – AI: What Next? ***bit.ly/AIWhatNext***

HOW TO THINK RATIONALLY ABOUT AI

The entire planet is hooked on the conversation about AI and its sinister future. But, if you ask those in the know (and we have) our future with machines looks entirely different to what the world's CEOs would have us believe. Here's how to stop worrying and, maybe, learn to love AI...

IS AI OUT OF CONTROL?

DR GARY MARCUS
Gary is an emeritus professor of psychology and neural science at New York University and a leading voice in artificial intelligence.

AI can do impressive things, but even the experts say it poses a very real threat to us. So should we put a hold on its development or is it already too late?

Many of the world's leading voices in artificial intelligence have begun to express fears about the technology. They include two of the so-called 'Godfathers of AI' – Dr Geoffrey Hinton and Prof Yoshua Bengio, who both played a significant role in its development.

Hinton shocked the AI world in May by quitting his role as one of Google's vice-presidents and engineering fellows, citing his concerns about the risks the tech could pose to humanity through the spread of misinformation. He even said he harbours some degree of regret regarding his contributions to the field.

Similarly, Nobel Prize-winning computer scientist Bengio recently told the BBC that he has been surprised by the speed that AI has evolved and felt 'lost' when looking back at his life's work.

Both have called for international regulations to enable us to keep tabs on the development of AI. Unfortunately, due to the fast pace at which the tech develops and the opaque 'black box' nature around how much of it operates, it's much more difficult than it sounds.

Although the potential risks of generative AI, whether it's bad actors using it for cybercrime or the mass production of misinformation, have become increasingly obvious, what we should do about them has not. One idea seems to be gathering momentum, though: global AI governance.

In an essay, published in *The Economist* on 18 April, Anka Reuel, a computer scientist at Stanford University, and I proposed the creation of an International Agency for AI. Since then, others have also expressed an interest in the idea. When I again raised the idea during the testimony I gave in the US Senate in May, both Sam Altman, CEO of OpenAI, and several senators seemed open to it.

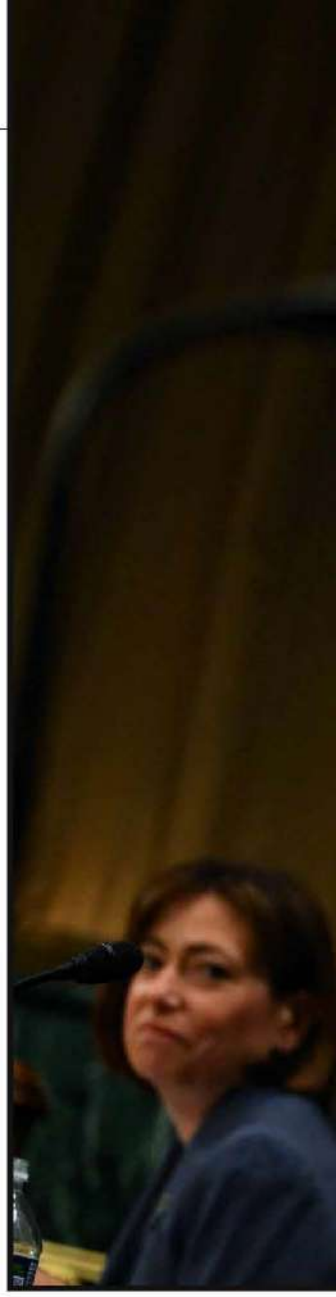
Later, leaders of three top AI companies sat down with UK prime minister Rishi Sunak to have a similar conversation. Reports from the meeting suggested that they too seemed aligned on the need for international governance. A forthcoming white paper from the United Nations also points in the same direction. Many other people that I've spoken to also see the urgency in the situation. My hope is that we'll be able to convert this enthusiasm into action.

At the same time, I want to call attention to a fundamental tension. We all agree on the need for transparency, fairness and accountability regarding AI, as emphasised by the White House, the Organisation for Economic Co-operation and Development (OECD), the Center for AI and Digital Policy (CAIDP) and the United Nations Educational, Scientific and Cultural Organization (UNESCO). In May, Microsoft even went so far as to directly ratify its commitment to transparency.

But the reality that few people seem to be willing to face is that large language models – the technology underlying the likes of ChatGPT and GPT-4 – are not transparent and are unlikely to be fair.

There is also little accountability. When large language models make errors, it's unclear why. It's also unclear whether their makers can be held legally responsible for any errors their AIs make, as the models are black boxes.

When push comes to shove, will the companies behind these AIs stand by their commitments to transparency? I found it disconcerting that Altman briefly threatened to take OpenAI out of Europe if he doesn't agree with the EU's AI regulation (although he walked his remarks back a day or two later).



ABOVE Gary Marcus at a Senate Judiciary Subcommittee hearing on the potential and pitfalls of AI, held in Washington DC in May 2023

ABOVE LEFT OpenAI CEO Sam Altman has sought to calm fears about his firm's work developing AI

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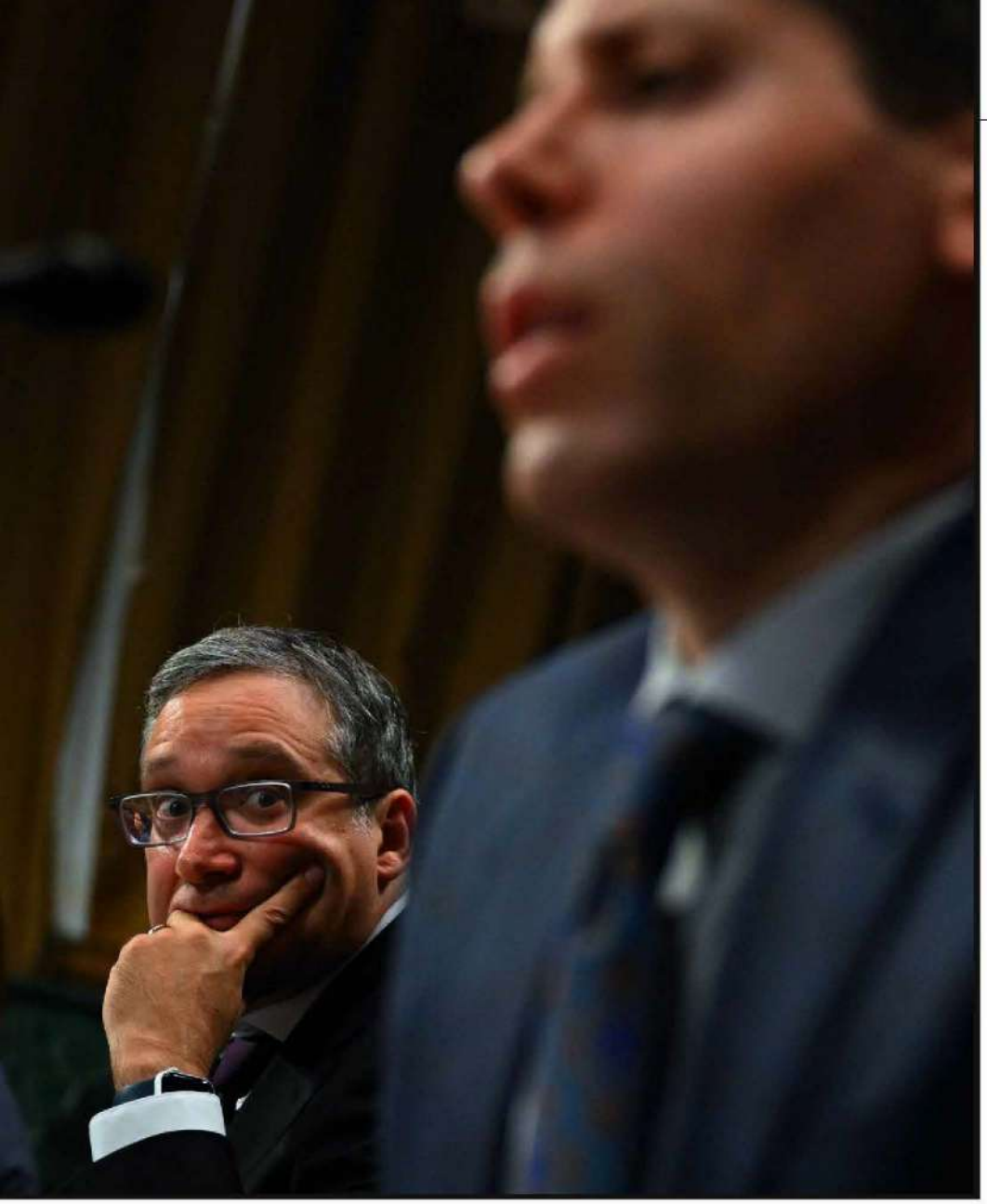


"WE ALL AGREE ON THE NEED FOR TRANSPARENCY, FAIRNESS AND ACCOUNTABILITY REGARDING AI"

More to the point, Microsoft owns a significant portion of OpenAI's GPT-4 and uses the tool in its own products (such as Bing), and neither Microsoft nor OpenAI has been fully forthcoming about how Bing or GPT-4 work, or about what data the tools are trained on.

All of which makes mitigating risks extremely difficult. Transparency is, for now, a promise rather than a reality.

Further complexity is added by the fact that there are many risks, not just one. So there won't be a single, universal solution. Misinformation is different from bias, which is different cybercrime, which is different from the potential long-term risk presented by truly autonomous AI.

Nevertheless, there are steps we can take (see 'What can we do?', right) and we should unify as a globe to insist that the AI companies keep the promises they've made to be transparent and accountable, and to support the science that we need to mitigate the risks that AI poses.

BBC SOUNDS

Listen to Prof Stuart Russell's Reith Lecture from 2021 on how AI could represent the most profound change in human history
bit.ly/AIReithLec

WHAT CAN WE DO?

There are steps we can take now to make developing AI safer…

1. Governments should institute a Medicines and Healthcare/Food and Drug Administration-style approval for large-scale deployment of AI models, in which companies must satisfy regulators (ideally independent scientists) that their products are safe and that the benefits outweigh the risk.
2. Governments should compel AI companies to be transparent about their data and to cooperate with independent investigators.
3. AI companies should provide resources (for example processing time) to allow external audits.
4. We should find ways to incentivise companies to treat AI as a genuine public good, through both carrots and sticks.
5. Create a global agency for AI, which has multiple stakeholders that work together to ensure that the rules governing AI serve the public and not just the AI companies.
6. We should work towards something like a CERN (Conseil Eurpéen pour la Recherche Nucléaire) for AI that's focused on safety and emphasises:
(a) developing new technologies that are better than current technologies honouring human values, and…
(b) developing tools and metrics to audit AI, track the risks and helps to directly mitigate those risks.

COULD WE BUILD RELATIONSHIPS WITH AI?

JUDITH DONATH
Judith is a writer, designer and artist whose work examines how new technologies transform the world, and is part of Harvard University's Berkman Klein Center for Internet and Society.

A real friend has a shoulder you can cry on. AIs may not have shoulders, but they'll listen to your troubles at any hour

Should an AI be your best friend? Even if you've never considered the possibility or think it's an absurd idea, it's worth contemplating, because in the near future there will be AI systems attempting to befriend you.

AI friends offer many benefits. They're available any time (even at two o'clock in the morning) and they never get bored (unlike your human friends, who may tire of hearing the same complaints about your job or partner).

But, as convenient as an AI friend might be, it's a friend with more costs than benefits.

One reason to be suspicious of AI companions is that you don't know their motives – or, more accurately, the motives of those who control them. They may be programmed to secretly support a political candidate, sell gadgets or sow discord. And, while most of us find it difficult to sustain a false front for an extended period and would feel (and inadvertently reveal) significant guilt and discomfort if we hurt or betrayed another, a machine, having no mind, has no such compunctions.

Machines are also becoming more persuasive than most humans. A recent study showed that pro-vaccine arguments produced by ChatGPT were more effective than those used by government agencies – an ability that could be easily redirected to advance more nefarious positions. Machine text is honed through innumerable interactions. You can see the process in the frequent changes to online headlines: back in the days of print-only newspapers, headline writers had one chance to write an attention-grabbing phrase; today, most publications constantly tweak their online text, watching how thousands of readers respond to the different variations and if a new version gets better results, in it goes. Similarly, all aspects of artificial friend-bots can be polished and perfected based on the effectiveness of their interactions with various users.

But what about AI friends that are created as genuine companions, not secret salesmen or undercover disruptors? Could they be a solution to our crisis of loneliness? Friendship is good for you: research has shown that people with an active and engaging social life live longer and are healthier and happier. Might artificial friends be the social equivalent of vitamin pills – helpful supplements when the ideal balanced diet (or lively circle of great friends) is unavailable?

Here the concern centres on the mind – or lack of mind – of the other. Think about the everyday experience of seeing something that would amuse a friend and making a mental note to tell them about it. Why do you do that? Maybe they're feeling down and you want to cheer them up. Or, perhaps you hope to impress them with your eye for the quirky or beautiful. In any case, your concern is with their inner experience, with how they feel or what they think of you. If something has no mind – no inner experience, just the capacity to imitate the words and behaviours of those who can think and feel – can that entity really be considered a friend?

Society is bound by our caring about what others feel. Empathy is part of this: we can feel the joy, or sadness, that someone we care about experiences. It's also important that we care what others think of us. Emotions such as shame or embarrassment can cause harm when they're used harshly or coercively, but they're also essential to keeping our society working – we 'do the right thing' and cooperate, at least in part, because we care how others perceive us. And having others think highly of us, or simply enjoy our company and care about our friendship, can be tremendously uplifting. The key is that these others must be conscious beings, able to form impressions and experience emotions. An artificial entity can be designed to imitate the external signs of emotions (to smile, sigh or cry) but it doesn't actually feel anything; it's not conscious.

Does this mean you should avoid interacting with AIs? Not necessarily. Properly designed, they can offer many benefits. They can help people think through difficult situations, practise social skills and provide insightful feedback. But they can do these things without the pretense of consciousness and emotion.

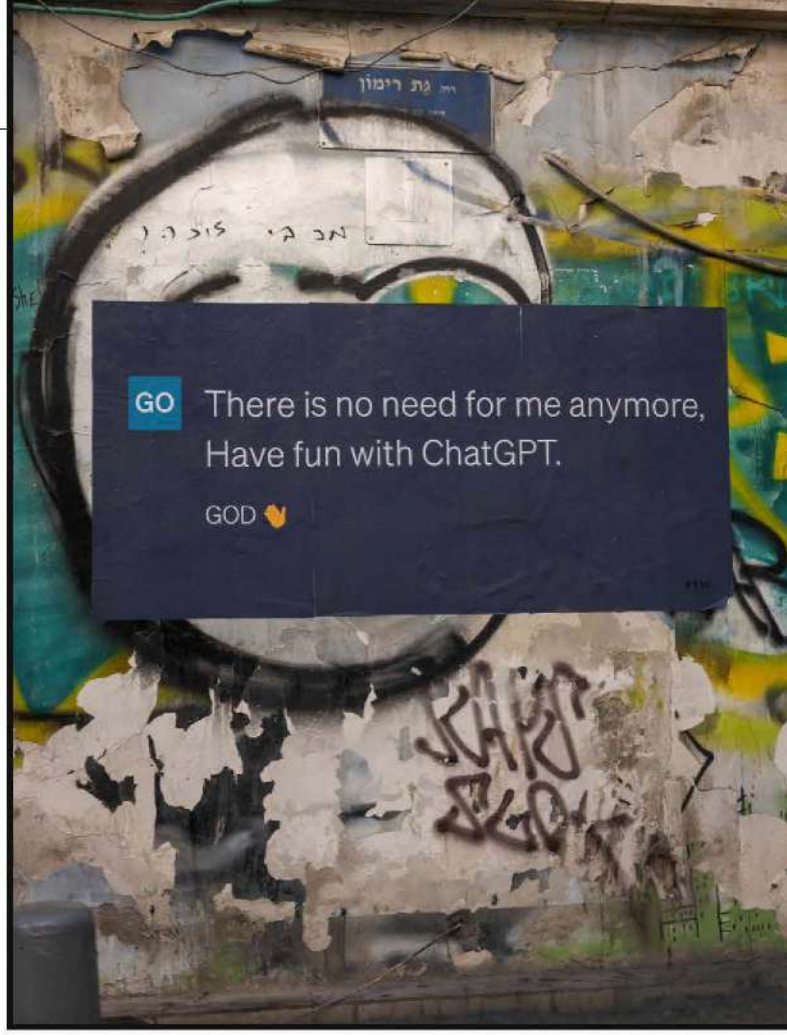
Living, conscious friends can be unpredictable and demanding. But, even as we increasingly interact with ever more sophisticated AIs, we need to embrace the complications of truly two-way relationships and to care about, and be responsive to, the experience of others.

RIGHT Replika says its AI companions, which have visual avatars, are there to listen and talk to you, and are always on your side

WILL AI MAKE US DUMBER?

PROF SHANNON VALLOR
Shannon is director of the Centre for Technomoral Futures at the University of Edinburgh.

What if 'will AIs pose an existential threat if they become sentient?' is the wrong question? What if the threat to humanity is not that today's AIs become sentient, but the fact that they won't?



GETTY IMAGES, REPLIKA

The release of OpenAI's ChatGPT has generated a flood of commentary, in the media and scientific circles, about the potential and risks of artificial intelligence.

At its core ChatGPT is a powerful version of the large language model known as GPT. GPT stands for generative pre-trained transformer; a type of machine learning model that extracts patterns from a vast body of training data (much of it scraped from the Internet) to generate new data composites, (such as chunks of text) using the same patterns.

CEOs of AI companies, politicians and prominent AI researchers are now publicly sounding alarms about the potential of tools like GPT to pose an existential threat to humanity. Some claim that GPT may be the first 'spark' of artificial general intelligence, or AGI – an achievement predicted to entail the arrival of sentient, conscious machines whose supreme intellects will doom us to irrelevance.

But as many more sober AI experts have observed, there's no scientific basis for the claim that large language models are, or ever will be, endowed with subjective experiences – the kind of 'inner life' that we speak of when we refer to conscious humans or other creatures for whom intelligence and sentience go hand in hand, such as dogs, elephants and octopi.

Everything we know about sentience is incompatible with a large language model, which lacks any coupling with the real world beyond our text inputs. Sentience requires the ability to sense and maintain contact with the multidimensional, spatiotemporally rich, flowing world around you, through sensorimotor organs and an embodied nervous system that's coupled with the physical environment. Without this coupling to reality, there's nothing to feel, nothing to be grasped, no reality to form as a stable subject within.

"HUMAN SURVIVAL IS NOT ENDANGERED BY AI, AT LEAST NOT FOR REASONS INVOLVING MACHINE SENTIENCE"

Does that mean AI is nothing to worry about? Some AI leaders, like Prof Yann LeCun, draw that conclusion. Their view is that today's AIs are unlikely to lead to AGI, so they pose no grave threat to humanity. Unfortunately, these techno-optimists are also wrong. The threat is very much there. We've just fundamentally misunderstood (or, in some cases, perhaps willfully misrepresented) its nature.

AI without the capacity to think is more dangerous than AI with it. What threat could AI possibly pose without minds or agency? In asking this question, we forget that an impostor can be more dangerous than a competitor.

Human survival is not endangered by AI, at least not for reasons involving machine sentience. But extinction is not the →

ABOVE Graffiti in Israel mocking the dangers of submitting ourselves to another's will

GETTY IMAGES X2, ARCHIE BROOKSBANK/@BLADESMANCONTENT

→ only risk. Losing the humane capacities that make our mode of existence worth choosing and preserving is another.

Imagine that aliens landed tomorrow and offered us a choice: Option A: they invade Earth and we take our chances resisting. Option B: they leave the planet alone, but only after replacing us with doppelgangers that carry on all the usual human-like activities (eating, talking, working) with no capacity for independent thought or creative vision, no ability to break from the patterns of the past and no motives beyond the efficient replication of the existing order. Is Option B the better choice? Or is it worse than the peril of extinction?

I'm not worried that today's AIs will turn into these mindless doppelgangers. I'm worried that *we* will. We're already willingly giving up the humane capacities that ChatGPT lacks.

Boosters of AI-powered writing apps are advertising, as a benefit, the chance to surrender the most important part of storytelling – envisioning where a story might go – to a bot that will simply present us with plausible preformed plot twists to choose from. People are lining up to thank the 'innovators' who show us how to train ChatGPT to write like we would, so that we may be liberated from the task of forming and articulating our thoughts.

The philosopher Hans Jonas warned us of the existential risk of a future 'technopoly' that celebrates the "quenching of future spontaneity in a world of behavioral automata," putting "the whole human enterprise at its mercy." He didn't make clear whether these automata will be machines or people. I suspect the ambiguity was intended.

Companies are now replacing scriptwriters, artists, lawyers and teachers – people who have crafted their talents over decades – with machines that produce output that's 'good enough' to pass for the labours of our thinking. The replacement is worrying, but far more concerning is the increasingly common argument that thinking is work we should be happy to be rid of. As one Twitter user put it: what if the future is merely about humans asking the questions, and letting something else come up with the answers?

That future is an authoritarian's paradise. Self-governance – not just the ability, but the desire and will to author our own stories – is the enemy of unaccountable power. Forcibly suppressing human agency is a lot harder than convincing people that the treasure they hold is worthless.

AI is causing real problems, right now, from algorithmic discrimination and disinformation to growing economic inequality and environmental costs. And these demand urgent solutions. But in terms of a future without humanity, AI isn't the threat. In fact, a future with sentient machines who think with us could, in principle, be every bit as good – and humane – as a future without them. The question is what kind of moral, intellectual and political value system the economic power behind today's AI will be used to sustain: one where thinking matters? Or one where it doesn't?

The talk about existential risk from AGI is a magician's distraction from what's going on right in front of us – not a mechanical uprising, but a silent campaign to devalue the political and cultural currency of humane thought. That's the endgame. Our humanity is the stake.

"WE'RE WILLINGLY GIVING UP THE HUMANE CAPABILITIES THAT CHATGPT LACKS"

ABOVE German philosopher Hans Jonas (right) talks to Germany's president Richard von Weizsäcker in 1992

COULD AI MAKE MUSIC THAT MOVES YOU?

LUCAS CANTOR
Lucas is the chief composer at the Melbourne Deep Learning Group at the University of Melbourne, Australia. He has won two Emmys for his music on US television, and has produced songs with Lorde and the Wu-Tang Clan.

AI can churn out tunes that mimic our best songwriters. But will any of these new tracks ever really resonate with us?

You might not think that an AI capable of making music would signal the end of free will, but others think differently. Particularly those who gathered at Mexico City's El Cantoral symphony hall in 2019 for the Latin American premiere of *Schubert's Unfinished Symphony, Finished With AI*.

BELOW The English Session Orchestra perform *Schubert's Unfinished Symphony, Finished With AI* at Cadogan Hall in London

I sat between my father and a Chilean movie star as the conductor led the orchestra in a performance of the symphony that I had written… Well, that I had sort of written. Before he died in 1828, Franz Schubert wrote half of the movements needed for a symphony and then abandoned the work. Over 190 years later, I 'finished' the symphony using melodies generated by an AI.

It was simple really. We trained an AI using Schubert's melodies and gave it the task of generating new melodies that sounded like the training data. Then I wove them together with some original ideas and an orchestra brought the result to life in that Mexican symphony hall.

As the orchestra finished Schubert's original work and began the music the AI and I had written, I could feel the crowd's energy shift from astonishment to indignation and fear. They seemed afraid that an AI might be able to make emotional symphonic music. You can see their point: an AI that makes emotional music could affect the emotional lives of thousands or even millions of people in a small, but profound way; just like a human musician does.

It's hard to understate the possible impact. If the demagogues of the 20th Century have taught us anything, it's that a person who can manipulate people's emotions on a massive scale can compel them to commit unspeakable atrocities. Imagine that power deployed at scale with the mechanical precision of AI, not just manipulating emotions with music.

All that considered, I understood the icy reception. But then something strange happened. The atmosphere in the room slowly changed. By the Symphony's finale, the audience's mood had turned from indignation to wonder. They hung on every cadence and I felt their surprise at every false ending until they were left breathless as the final chord decayed into silence.

Positive and negative, people reacted very strongly to AI's symphonic debut. The main reason, I think, is that even →

→ though most people don't believe that AI can create something enjoyable, they, at least partly, *did* enjoy the *Unfinished Symphony*.

Enjoyment in music implies that there's something in the music that the listener connects to, a perception of shared emotion. But, in the case of AI music, an emotion shared with who? AI, as of yet, has no emotions. So what is the meaning of music made without an emotional composer? The unsatisfying answer is that music has no objective meaning. A composer can decide how a piece of music sounds, but it's the *listener* that decides what it means.

And here's where things get really interesting. The meaning we assign to music depends on its context – how the piece connects to other elements in our lives. Without context, music is like the results of a game whose rules have been lost: an obviously intentional creation, but with no apparent utility. No matter how it's created, music doesn't exist in a vacuum to the listener.

As it continues to evolve, AI music will develop its own context and within that context, it could be as emotional as any style of music. Certainly, it'll be different from human-made music. Its *rules* will be different. It'll mix existing genres to create new ones; it'll combine instruments that we wouldn't think of combining. Some people may even come to prefer it to human-made music.

If you believe that symphonic music made by 18th Century humans has inherent emotional value then keep in mind that you've heard Western music for your entire life. The context for this music is part of who you are. It's part of society. It's *emotional* to you because *you* have the context to appreciate it.

Considering this, it's strange that I'm now always asked the same question after a performance of the *Unfinished Symphony*: "Who put the emotion in that music: you, the composer, or the AI?"

Answer: it's *you*, the listener, that creates the emotion – it's the connections you draw from your life to the music.

That's not the question they really want to ask, though. There's a deeper question that most people are too afraid to ask right now: "Are my emotions so simple that they can be manipulated by a machine?"

In my experience, this could be possible one day. If a modestly capable music AI in 2019 could stir up indignation, fear and even a little wonder in an audience in Mexico City, maybe AI can have a more potent effect on our emotional lives than we'd like to admit.

And if AI really could manipulate our emotions even slightly, it may be able to do so in ways so subtle that it could cause us to believe that any ideas were our own. An AI that could manipulate our emotions could rob us of our free will without us realising it. It may even be happening already.

COULD AI SAVE US FROM EXTINCTION?

LORD MARTIN REES
Martin is the Astronomer Royal and co-founder of the Centre for the study of Existential Risk. His latest book is If Science Is To Save Us *(Polity, £20)*

Scientific advances have helped us create our current world. But what does future hold, given the potential of AI?

Scientists are rotten forecasters of the future. But two trends can be confidently predicted. First, the world will get more crowded. There'll be more than 9 billion people by 2050. Nourishing them all will require genetically modified crops,

LEFT Post-human artificial (or rather, inorganic) intelligences could allow our civilisation to expand across the galaxy

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food made from insects and artificial meat. Second, the world will get warmer and politicians won't prioritise the long-term measures needed to deal with climate change unless there's a clamour from voters, even though science offers us a roadmap to a low-carbon future (technically advanced nations should expand research and development into all forms of low-carbon energy generation, storage and distribution; the prosperous north can thereby reach net zero and the impoverished global south can leapfrog to clean energy).

That's why we should be evangelists for new technology – without it the world can't provide the food and sustainable energy needed for an expanding population. But we should also be wary, as new technologies, such as AI, may be hard to control.

AI will undoubtedly become more intrusive and pervasive in the future. Records of our movements, health and financial transactions will be stored in the cloud and managed by a multinational quasi-monopoly. The data may be used for benign reasons, such as medical research, or to warn us of incipient health risks, but its availability to internet companies is already shifting the balance of power from governments to globe-spanning conglomerates.

Clearly, machines will take over much of the manufacturing and retail sectors. They can supplement, if not replace, many white-collar jobs: accountancy, computer coding, medical diagnostics and even surgery. In contrast, some skilled service-sector jobs – plumbing and gardening, for instance – require non-routine interactions with people and will be among the hardest jobs to automate.

The digital revolution is already generating enormous wealth for innovators and global companies, but preserving a healthy society will require redistribution of that wealth. Indeed, to create a humane society, governments will need to vastly enhance the number and status of those who care for the old, the young and the sick. There are currently far too few these sorts of carers, and they're poorly paid, inadequately esteemed and insecure in their positions. Their work is also far more fulfilling than the work performed in call centres or Amazon warehouses that AI can usurp.

AI doesn't only replace, however; it can also help. AI already copes better than humans with data-rich, fast-changing networks. It could provide the Chinese with a highly efficient planned economy, one that Marx could only dream of. And AI can help science too, in areas like protein folding and drug development. But it's beyond Earth, that AI has the most spectacular scope. Indeed, I have argued that the sending humans on space voyages (which is vastly more expensive than sending robots), should receive no taxpayer funding. The practical case for favouring humans is minimal – leave that to Elon Musk and Jeff Bezos. Between them and the various national space agencies, humans may have established bases beyond Earth by the year 2100. But don't ever expect mass emigration from Earth. It's a dangerous delusion to think that space offers an escape from our problems. Dealing with climate change on Earth is a doddle compared to terraforming Mars.

Nonetheless, we should cheer on these brave human space adventurers. And here's why…

They'll be ill-adapted to a Martian habitat, so they'll have a compelling motive to redesign themselves. It's them, not those of us adapted to life on Earth, who will spearhead the post-human era.

If post-humans make the transition from flesh and blood to fully artificial (or rather, inorganic) intelligences, they won't need an atmosphere or even gravity, so it's in deep space – not on Earth, or even Mars – that non-biological 'brains' may develop powers that we can't imagine. They may end up being as different, mentally, from us as we are from slime mould. So even if intelligent life originated only on Earth, it need not remain here: AI could jump-start a diaspora whereby ever more complex intelligence spreads through the galaxy.

But let's refocus from the science fiction of the far future, closer to the here and now. This century is special. It's the first, in Earth's 4.5-billion-year history where one species – ours – holds the planet's future in its hands. Our intelligence could inaugurate billions of years of post-human evolution, even more marvellous than that which led to us. On the other hand, humans could trigger biological, environmental or cyber catastrophes that foreclose all this potential.

If science is to save us, we need to think globally, rationally and long-term – empowered by science, but guided by values that science alone can't provide. **SF**

CAN SCIENCE TURN A NIGHT OWL INTO A MORNING LARK?

If you're a night owl, you probably have a hard time dealing with a world that starts at 9am. But can science help you tinker with your body clock to make it easier to rise with the larks?

by **IAN TAYLOR**

Anyone who's not a morning person is reminded, frequently, that they're not a morning person. For me, it's being used as a barely sentient climbing frame when my children charge in at dawn. It's the brain fog that takes a couple of hours to shake off at the start of each day. It's the mild despair at seeing messages from colleagues who are already being productive, while I'm still summoning up the coordination required to pour out some breakfast cereal.

If you're a night owl rather than an early-bird lark, the world is not organised in your favour. For most of us, work or school starts between 8-9am. If you're a shift worker or a parent to young children, then your day likely starts even earlier. But for around 30 per cent of the population (me included) this runs counter to our biology. We're slow to rise and slow to feel wakeful or energetic. In some cases (naming no names), we might be a little grumpy and monosyllabic, too.

And that's because of our chronotypes, the body's natural tendency to sleep and wake at certain times. Linked to our circadian rhythms – the internal clock that regulates a person's sleep-wake cycle – chronotypes describe our sleep patterns, and the tempo of behaviours and characteristics that go with them. →

GETTY IMAGES X2

→ Most of us think there are two chronotypes: night owls, like me, who feel productive, creative or just wide awake later in the evening; and morning larks, who can spring out of bed and jump straight into their running gear or a busy inbox.

In truth, chronotypes exist not as a binary but on more of a spectrum, and there are intermediary types that have some of the characteristics of both owls and larks. Even within a given chronotype, there's a certain amount of elasticity. It's why morning people can stay up late and evening types can, when pushed, catch early-morning flights.

"Your internal clock doesn't run at exactly 24 hours," says Dr Victoria Revell, a sleep researcher and expert in circadian physiology at the University of Surrey. "For most people, it runs slightly longer than 24 hours. So it needs daily adjustment to keep on a 24-hour schedule."

That flexibility opens up an intriguing opportunity for a night owl like me: is it possible to coax my body clock into a slightly earlier rhythm? In a world where sleep can be hacked, tracked and optimised, can I turn myself into a lark – or at least a better owl?

"The main thing with chronotypes is that, yes, there's a genetic predisposition, but they're not set in stone," says Edward Gorst, a London-based sleep coach. "There's a couple of hours' wiggle room."

With the help of researchers, sleep coaches and an alarm set to loud, I'm going to give it a go. But first, I need to understand the science...

THE HUMAN SLUMBER SYSTEM

Why are some people programmed to get up earlier than others? There is no one clear answer to this question; instead, the explanation is a fuzzy mix of genetics, evolutionary adaptations and our environments and behaviours.

The genetic component is down to a gene called PER3, which regulates certain elements of our circadian rhythms. And the reason we have different expressions of PER3 could be linked to our ancestors' survival instincts.

In 2017, a group of researchers suggested that different chronotypes may have evolved in groups of hunter-gatherers, so that there could always be somebody to keep watch while others slept. (Unfortunately, modern office managers fail to recognise the same benefits.)

"WE KNOW CHRONOTYPES CAN CHANGE, BECAUSE THEY DO CHANGE, USUALLY WITH AGE"

Physically, the tempo of our circadian rhythms is set in a small region of the brain called the suprachiasmatic nucleus or SCN, explains Prof Malcolm von Schantz, a sleep researcher at Northumbria University. "It's this small lump of neurons located deep in the brain, in the hypothalamus, that's a sort of circadian control station," he says.

"The SCN essentially coordinates circadian rhythms in humans and other mammals. It's sort of the master clock, which controls all the peripheral clocks that we have in our organs."

Neurological control units and genetic predisposition make it sound as though our chronotypes are biologically hardwired. So, is it unrealistic to even try and override them to become a morning person? Not necessarily.

We know chronotypes can change, because they *do* change, naturally – usually with age. "We see a trajectory of chronotype across our lifespan so that in our teens we become increasingly evening types," von Schatz says, explaining why teenagers often find it hard to get out of bed in the morning.

GETTY IMAGES X3, SCIENCE PHOTO LIBRARY

"At the end of adolescence, probably around age 18-20, that's where we have a sort of lifetime maximum of 'eveningness'. After that, there's a gentle and continuous, pretty much linear slope, towards increased 'morningness'."

It doesn't always feel like it, but this means I'm already becoming more of a morning person. In my early 40s, I'm approaching what might be the middle of that gentle slope. But if I want to speed up the process, I'll have to somehow tinker with my internal body clock. And, according to the science, the best way to do that is to see the light.

HACK THE LIGHT FANTASTIC

There's a reason sleep researchers caution against bringing your smartphone into the bedroom. "Light is by far the most important way in which our circadian rhythms are adjusted," says von Schantz.

And not just any light, but blue light – the stuff we get from natural daylight and the same stuff that's beamed into our retinas from the devices we gaze at all day long.

"We know that if you have light in the evening, it actually shifts your clock later in time," says Revell. "People who are sitting in front of their blue [light] screens or sitting with all the lights on late in the evening, not only are they waking themselves up, they're actually delaying their clock, so it's harder to fall asleep. They're tired, but because they've had that light, they've shifted their clock later in time, almost as if they'd flown two hours west."

It goes back to the SCN, that circadian control centre in your hypothalamus. According to von Schantz, the SCN only responds to information from the retina during two fairly narrow time windows: one window is around 7am and the other is around 11pm.

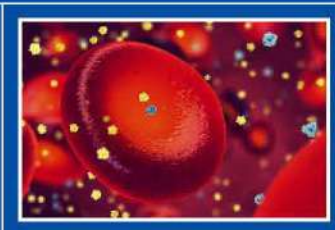
"Those time windows are crucial, for evening types in particular," he says. "You really need that light in the morning because you need to work harder on the daily task of advancing your body clock."

It's one of the reasons why sleep coaches recommend getting out of bed as soon as you wake up, rather than hitting snooze and staying in your shady bedroom. If possible, go outside for a walk, have breakfast in the garden or invest in a SAD (seasonal affective disorder) lamp, which uses the same kind of blue light and is especially helpful on those dark winter mornings. →

The curse of the night owl

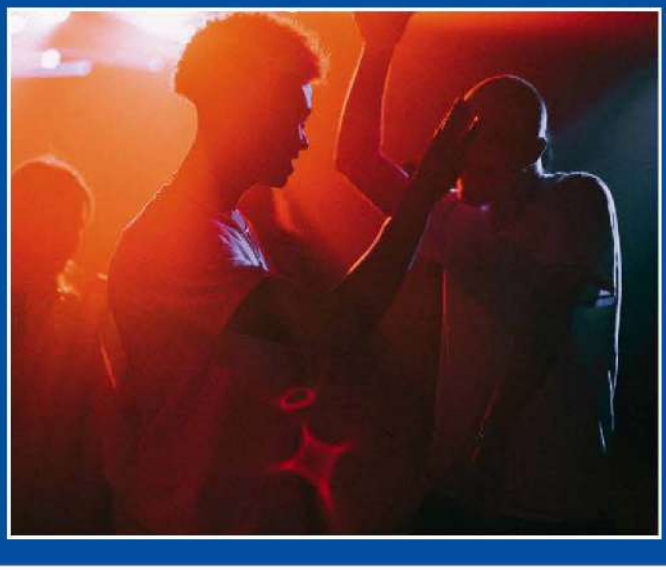
It's not just social jet lag that makes life tough for night owls. Studies show they're also at an increased risk of a number of health issues, including...

DIABETES AND HEART DISEASE
This is partly because early birds tend to use their fat stores as a source of energy, say researchers at Rutgers University.



DEPRESSION
Multiple studies show that night owls are more prone to depression, but one from Harvard Medical School suggests that going to bed and getting up one hour earlier can reduce the risk by 23 per cent.

BREAST CANCER
University of Bristol researchers found that women who rise early have as much as 48 per cent lower risk of developing breast cancer than night owls (although chronotypes may be less important than factors like smoking or diet).



→ In the evening, do the opposite. "As an evening type, I'd recommend you avoid light in the late evening, around 11pm to midnight," von Schantz says. "Evening types are actually more likely to expose themselves to light at that time. That's the dilemma. Because you're awake, you're more likely to seek out light and doing so reinforces the chronotype."

For people who want to shift themselves to an earlier sleep cycle, Revell recommends turning on the night-time setting on your devices (or better still, put them completely out of sight). You can also purchase glasses with lenses that filter out blue light.

"These steps sound simple and they are simple, but light is really powerful," says Revell. "We use it as an intervention in a lot of our studies. One of my colleagues recently published, a paper looking at lighting in care homes and showing that by improving the light during the day you can even reduce falls."

STICK TO A ROUTINE THAT WORKS

Light is an immensely powerful tool to help adjust your sleeping patterns, but it's not an overnight fix. Researchers say that backing it up with other lifestyle factors can smooth your transition to becoming a morning person.

First and foremost among these is good sleep hygiene, which will make it easier to drop off and increase the quality of the sleep you get. Some of it you already know: your room should be dark, quiet and comfortable. If you can, set the temperature to somewhere between 16-20°C. Exercise daily and find the pillows or podcasts that work for you.

Whatever your habits – stick to them. Routine is key, says Revell. "We've done studies where we try to adapt people to a new time zone. And the concept is we shift them before they fly so that when they get to their new time zone, they can operate straight away. So gradually shift your bedtime a little earlier.

"Say you go to bed at 1am and you'd rather go to bed at 11.30pm. That's perfectly plausible. Just remember that if you're genetically predisposed to be an evening person, you're never going to become someone who's happy to go to bed at 9pm. But you can shift your clock by an hour or two within three or four days."

EAT, SLEEP, REPEAT

Whether you're a lark or an owl, many of us instinctively switch the kettle on as soon as we get up in the morning. Drinking tea or coffee first thing helps us break the sleep inertia that makes us feel groggy because, as we all know, the caffeine in those drinks is a stimulant. That's also why it's important not to drink caffeinated beverages late in the afternoon or evening, if you want to get to sleep early.

"Caffeine has a long half-life," says Revell. "It stays in your system for hours. So if you're drinking coffee at 5pm, the caffeine is still going to be in your system when you try to go to bed."

SCIENCE PHOTO LIBRARY

The hormone melatonin (seen here under a microscope) is secreted by the pineal gland in your brain at night to help induce sleep

Sugar and alcohol have similar effects and can not only disrupt sleep quality, but also its onset. So what can you eat or drink to help you get to sleep earlier and feel more awake in the morning?

Many articles offering advice on sleep will point you towards foods that are rich in an amino acid called tryptophan, including milk, cereal, nuts or turkey.

The idea behind the advice is that our bodies naturally turn tryptophan into the hormone melatonin, which helps us regulate our sleep. In fact, melatonin is sold as a sleep aid in some countries (it's available in the UK, but only as a prescription medication).

There is, however, only weak evidence to support the idea that eating lots of tryptophan-rich foods will help you sleep better. "You may be able to indirectly increase your melatonin levels that way," says von Schantz. "But it's unlikely to make a big difference, especially compared to something like light."

The only other consideration when it comes to diet is when you eat, explains Revell. "Your metabolism changes across 24 hours, so the way your body will metabolise a cheese sandwich at midnight compared to midday is completely different," she says.

"If you're eating something late in the evening, your glucose [sugar] levels stay elevated, and your lipid [fatty compounds] levels stay elevated a lot longer, which is why shift workers that eat during the night often have a higher risk of cardiovascular disease and diabetes." In other words: night owls, beware of the munchies.

CAN TECH AND DATA HELP YOU DOZE OFF?

In recent years, sleep has become big business. With record numbers of people having problems with their sleep, an entire industry has sprung up to help, offering everything from black-out curtains and ergonomic pillows to wearables that track your biomarkers during the night and 'nearables' that monitor your unconscious body via radar or a sensor under your mattress.

Add to those the many tips from a growing army of podcasters and YouTubers who experiment with everything from cold showers (to make you more alert in the morning), to mouth tapes that force you to breathe through your nose during the night (to combat snoring and sleep apnea).

At her lab at the University of Surrey, Revell and her colleagues test sleep trackers and other devices. Although she believes that they can be helpful for people who want data about their sleep, she cautions that some are better than others.

Sleep coach Ed agrees. "The trouble with some of the sleep trackers is that they're not all accurate and, more than that, they can just reinforce what you already know: you've had a bad night's sleep," he says. "That, in itself, can cause anxiety and exacerbate the issue."

DOES ANY OF IT WORK?

During the course of writing this article, I tried out some of the techniques mentioned in an effort to wrench my sleep-wake cycle forward a little. With the caveat that this study has a sample size of precisely one lanky Welshman, I do feel a difference, even if my 'morningness' is impossible to measure.

So what worked? It's hard to single out any one thing, because I tried a few in tandem. I've eaten breakfast in the garden to maximise my morning light and started turning my phone onto night mode as soon as the kids are in bed.

My schedule is earlier and more regimented, as I now go to bed at 11.30pm rather than 12-12.30am (and I leave the phone downstairs). But this is partly because I've noticed that I feel more tired in the evenings.

The mornings are less consistent because, even if I set an alarm, my kids often rise before it. And even if I feel more alert in general, it's still a violent jump-start to the day when a six-year-old belly-flops onto your midriff at 6.20am.

Some things weren't for me at all. Taping my mouth shut felt more likely to bring on a panic attack than a good night's sleep, and wearables do little besides bore me. Something Malcolm von Schantz said to me about them certainly rings true, for me though: "Your own experience is the best marker. Rather than listening to a fancy device, listen to your body." SF

"IF YOU'RE DRINKING COFFEE AT 5PM, THE CAFFEINE IS STILL GOING TO BE IN YOUR SYSTEM WHEN YOU TRY TO GO TO BED"

by IAN TAYLOR
Ian is a freelance science writer and the former deputy editor of BBC Science Focus magazine.

Q&A

Email your questions to questions@sciencefocus.com or submit on Twitter at @sciencefocus

YOUR QUESTIONS ANSWERED

SAMANTHA OSBORN, VIA EMAIL

WHY DO I SELF-SABOTAGE SO MUCH?

Self-sabotaging – also known as 'self-handicapping' by psychologists – is when you knowingly do things that are likely to harm your chances of success, be that in the context of academic tests, performance at work, sport or relationships.

For instance, say you deliberately choose not to rehearse for a work presentation. Or you have a running race coming up and you decide not to train for it. In a relationship context, perhaps you decide to start ignoring your partner's texts, even though you're happy in the relationship. In all these cases, behaving this way might sound strange and self-defeating. But research suggests there is a logic to self-sabotaging: it's something people often do as a way to protect their self-esteem and alleviate their fears of failure or abandonment.

For instance, suppose you purposefully avoided doing any preparation for your presentation at work and, as a result, it went really badly. You could put that failure down to the fact that you didn't prepare, rather than your presentation saying anything fundamental about you as a person or your skills. Similarly, if you came last in the running race, you could shrug off that disaster as being down to the fact that you didn't bother doing any training.

In the case of your ignoring your partner's texts, if they decide to break up with you, you could put that rejection down to the fact that you'd been ignoring them – rather than the split being anything to do with them not liking you anymore or choosing to go off with someone else.

In short, self-sabotaging is a way to protect your ego by setting up a perfect excuse for if and when failure or rejection occur. People with a fear of failure and/or low self-esteem are more likely to use self-sabotaging in this way. In the short-term, it might even help you to feel better about yourself, and it's a way to protect your image in the eyes of others. It's an

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HOLLY MCHUGH
Science writer

DR HELEN SCALES
Marine biologist

DR ALASTAIR GUNN
Astrophysics lecturer

DR CLAIRE ASHER
Science journalist

DR NISH MANEK
GP and medical expert

LUIS VILLAZON
Science and technology writer

inadvisable strategy however, because, in the long-run, you are – of course – going to increase your chances of failure and rejection.

If you really wanted to give a good presentation, you'd have been better off preparing; to win the race, you ought to have trained; and if you really hoped to stay with your partner, you definitely shouldn't have upset them by ignoring their texts.

If you've fallen into the habit of self-sabotaging, it's going to take time to break it, but a healthier approach is within your reach. One strategy that will help is adopting a so-called 'mastery mindset', which involves seeing challenges as a chance to learn and improve, rather than as a profound verdict on your inherent skills or value. Do the best you can in the work presentation or running race and if it doesn't go perfectly, think about what you could do better next time.

Another helpful strategy is to practise self-compassion, which involves treating yourself with the same kindness you would

"RESEARCH SUGGESTS THERE IS A LOGIC TO SELF-SABOTAGING: IT'S SOMETHING PEOPLE OFTEN DO AS A WAY TO PROTECT THEIR SELF-ESTEEM"

a close friend or relative, and recognising that your self-worth isn't dependent on any particular opinion or relationship outcome. If you feel yourself getting close to your romantic partner, try to get comfortable with those feelings of vulnerability and remind yourself that if the relationship ends one day, it really doesn't mean you're inherently broken or unlovable. ***CJ***

CHARLIE HANEY, VIA EMAIL

JADE ROLLERS: DO THEY ACTUALLY WORK OR DO THEY JUST FEEL NICE?

Jade rollers are rolling devices made of jade, a stone that has been used traditionally in skincare for decades. Jade is said to have energy-healing properties that keep your skin youthful, and the cold touch of the stone apparently soothes inflammation. The rollers are said to promote lymphatic drainage in the face, which reduces puffiness. Unfortunately, in reality, the hype doesn't stand up – jade rollers are about as effective as any form of facial massage when done correctly. Facial massage can help skin to look brighter and less puffy, but if you're looking for substantive change, sadly, that's unlikely to happen with a jade roller. ***NM***

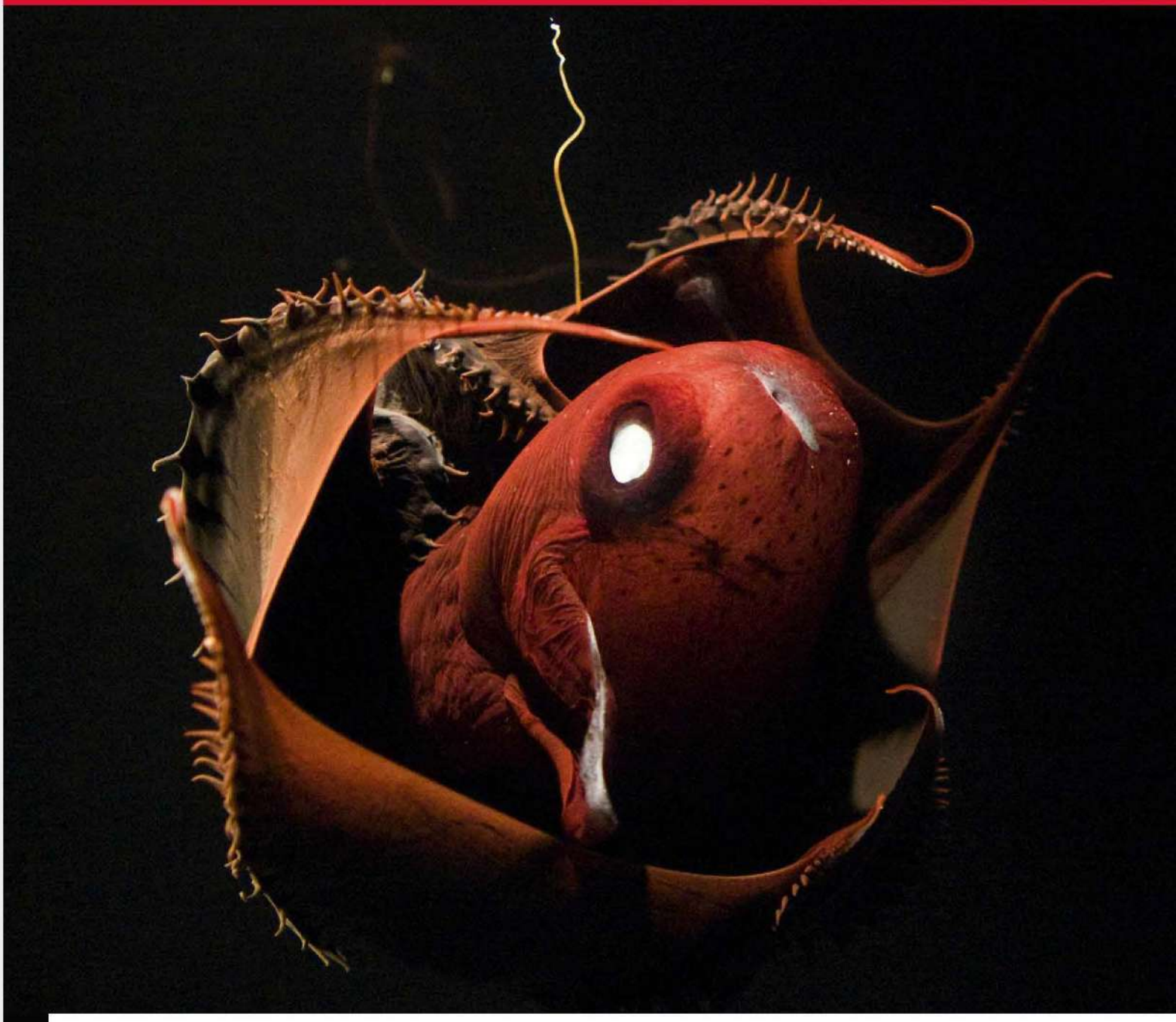
LAWRENCE HANCOCK, CUMBRIA

IS THERE A KNOWN LIMIT ON HOW TALL A TREE CAN GROW?

The world's tallest tree is a 116m (380ft) redwood in California, USA. Scientists think it comes close to the maximum height a tree can grow. Trees grow very tall when water and nutrients are plentiful and there is intense competition for sunlight. But as they grow, gravity gets stronger. Plants and trees carry water to their leaves for photosynthesis in a tube called the xylem. If there isn't enough water, or gravity is very strong, this water column can break, creating potentially deadly air bubbles. This places an upper limit on tree height, which theoretically lies somewhere between 122m and 130m (400-426ft). ***CA***

GETTY IMAGES X2 ILLUSTRATION: JOE WALDRON

NATURE'S WEIRDEST CREATURES

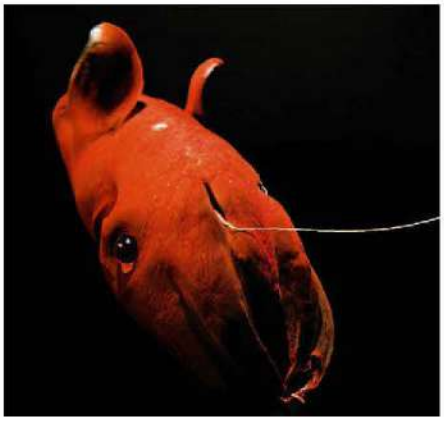


VAMPIRE SQUID

With their blood-red skin, white snapping beak and hooks arranged along their eight arms, the vampire squid is a spine-chilling apparition of the deep. Their scientific name, *Vampyroteuthis infernalis*, doesn't help matters – the vampire squid from hell. But it's a highly misleading name. For one thing, they aren't actually squid, but distant relatives of octopuses and squid, and the only living members of their family, the Vampyroteuthidae. And they're not bloodsucking beasts from the underworld. They're actually quite gentle and small – at most, their bodies grow to 30cm, roughly the size of a rugby ball.

For a long time, scientists had no idea what vampire squid eat, and generally assumed they were predators lurking in the dark waiting to leap on live prey. Then, in 2012, researchers from Monterey Bay Aquarium Research Institute in California made a breakthrough and published a study revealing that vampire squid have their own unique way of feeding.

A deep-diving robot equipped with video cameras was dispatched into the deep and beamed up images of a vampire hovering in the water column. It unfurled two long thin filaments, eight times the length of its body and used them to



collect fluffy particles of organic matter, known as marine snow, which trickle down from above. Marine snow is not nearly as nice as it sounds. It's a mixture of dead plankton and their droppings, all stuck together with goo. Now and then, the vampire squid on camera reeled in its snow-covered filaments, wiped them over its arms, packed the marine snowflakes into little snowballs, then passed them to its mouth and swallowed. It turns out these are snow-eating squid.

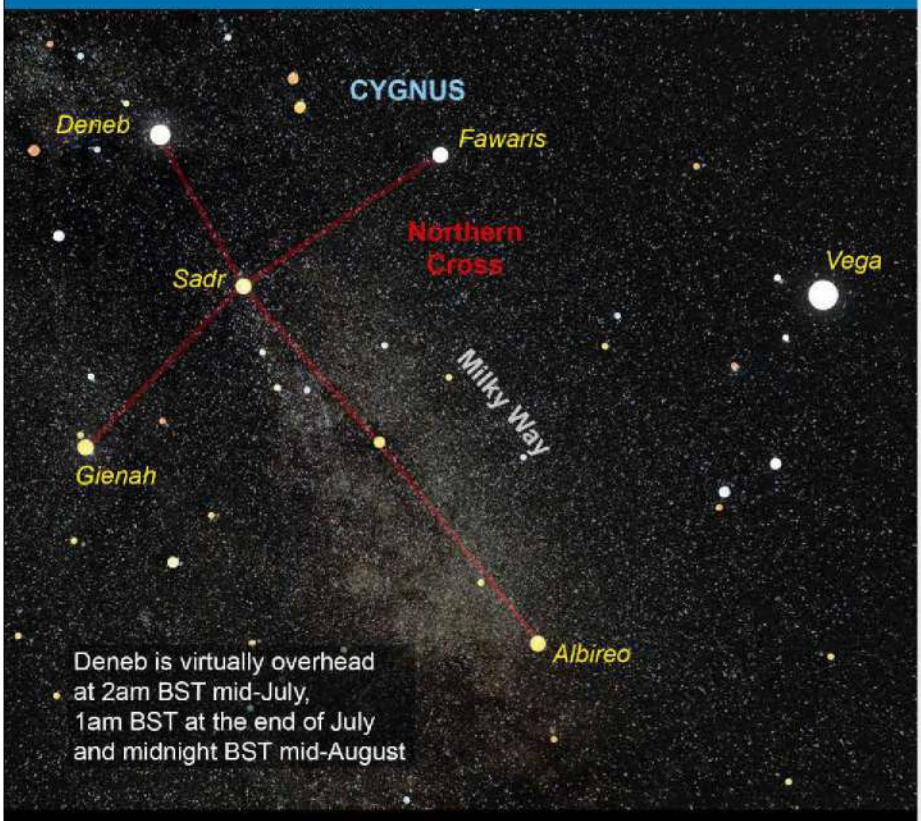
Scavenging for falling particles is an excellent strategy for vampire squid, which live in the depths of the ocean where there's little food around. There's also not much oxygen to breathe. They live between around 600 and 1,200m down, in a part of the deep sea known as the oxygen minimum zone. So, it makes perfect sense that vampire squid have evolved an energy-saving strategy. Rather than dashing around in search of prey, they can float in the water column and gently gather marine snow.

Like all animals living in the deep, vampire squid need to avoid becoming someone else's dinner, and they have various tactics to avoid capture. When threatened by an attacker, they pull their arms over their heads and turn themselves inside out, so those fearsome looking spikes stick out in all directions. Scientists refer to this as the pineapple pose.

Vampire squid also have an ability that's common among deep-sea species: they can light up their bodies. They have a glowing dot of bioluminescence at the end of each arm. It's not entirely clear what function their lights serve, but perhaps they use them to startle attackers, flashing stars in front of a predator's eyes. They can also release a cloud of glowing goo as a distraction, before making a quick escape into the dark. ***HS***

STEVE DOWNER/ARDEA PICTURE LIBRARY X2 ILLUSTRATION: PETE LAWRENCE

ASTRONOMY FOR BEGINNERS



THE MAGNIFICENT MILKY WAY

WHEN: SUMMER

Now that we're past the shortest night of the year, which occurs at the summer solstice on 21 June, the nights are slowly getting longer and darker. The beautiful Milky Way, or the part of it we can see from the UK at least, moves into prime position around this time too.

The Milky Way represents light from billions of stars in our home galaxy. Too far to be seen individually with the naked eye, their light merges into a mistiness passing across the sky. The 3D shape of our galaxy is similar to what you'd get by putting two fried eggs back-to-back. In this somewhat messy model, the Sun sits two thirds out from the central yolks, closer to the edge, in the white of the eggs.

In reality, this places us within the Milky Way's spiral arms. Looking along the plane of the galaxy gives us a view through dense star clouds, while looking out at right angles to the plane, gives us a view through far fewer stars. In summer, the view is along the plane towards the Milky Way's core, where the star fields are rich and bright.

The core never gets high above the UK's southern horizon, thus reducing its visual impact. The brightest part from the UK is that which passes through Cygnus the Swan, down the vertical of an asterism – or unofficial pattern – known as the Northern Cross.

You're unlikely to see the Milky Way from a city, town or even a badly lit village. The best views will be from the countryside where there are few light sources around. Alternatively, if you can get to a dark bit of coastline, that works well too. Plan a trip when the Moon is out of the way and your effort will be rewarded by a spectacle like no other. ***PL***

by PETE LAWRENCE
(@Avertedvision)
Pete is an astronomy expert and presenter on BBC's The Sky at Night

WATCH *THE SKY AT NIGHT* ON BBC FOUR AND BBC IPLAYER
BBC FOUR

KHADIJAH HORN, VIA EMAIL

COULD AN ASTEROID IMPACT EVER CHANGE EARTH'S ORBIT?

Theoretically, any two objects colliding with each other will involve a transfer of momentum that alters their trajectories. So, even a micrometeorite, weighing less than a gram, could result in an imperceptible change in Earth's orbit around the Sun. However, things are not quite that simple.

Generally, the larger the impacting object the larger the effect of its impact. But the effect depends on many things, for example: the density and tensile strength of the impactor; the geology of the impact point; and the angle and velocity of the impact.

Crucially though, the transfer of momentum to Earth during an impact is far from total. This is because the impactor is often fractured or vaporised prior to hitting Earth's surface. The large kinetic energy of the impactor is converted mostly to heat (due to friction as it travels through Earth's atmosphere) and only a small amount is felt as mechanical energy. Even this small amount of mechanical energy goes mostly into deforming and fracturing Earth's surface and destroying the impactor. Almost none of the impactor's energy ends up changing Earth's momentum.

Scientists are aware of numerous large impact sites that survive on Earth's surface. The largest, Vredefort Crater in South Africa, implies an object about 20km in size, travelling at up to 90,000 km/h, hitting Earth about 2 billion years ago. That object was probably just 100-millionth of the mass of Earth. This huge mass difference, and the fact that very little momentum is transferred, implies that no known impact event has significantly altered Earth's orbit.

This doesn't mean that these impact events are without consequences. Most are associated with mass extinction events, such as the Chicxulub event, which accounts for the demise of the dinosaurs. Their immediate effect is to completely vaporise anything in their vicinity and perhaps create mega-tsunamis, earthquakes and volcanism. They're also thought to result in significant changes to Earth's atmosphere and the global climate. But what they don't do is throw Earth out of its orbit.

However, things were different in the Solar System's early history. Then, there were many more and much larger objects capable of impacting the infant planets. It's widely believed that the Moon is the result of a catastrophic impact with the primitive Earth. The orientation of Uranus's rotation axis (almost perpendicular to its orbital plane) suggests that an Earth-sized object crashed into it 3 to 4 billion years ago. These kinds of impacts, where the impactor's mass is a significant fraction of the planet's mass, would certainly have been powerful enough to alter their orbits. So, it's probably safe to say that all the planets of the Solar System have had their orbits altered by impacts. Exactly when, how and by what is, unfortunately, impossible to say. ***AG***

LUCINDA COX, SUSSEX

WHY DO OLD BATTERIES LEAK?

Batteries generate electricity by chemical reactions that move electrons from one terminal to the other. Ordinary alkaline batteries use a potassium hydroxide gel as the conductive electrolyte, and the reactions in the gel generate a small amount of hydrogen gas. Since the battery is sealed, the pressure in the cell gradually builds and eventually causes tiny ruptures along the seams of the metal casing. The potassium hydroxide reacts with CO_2 in the air to form a harmless crust of potassium carbonate, but the potassium hydroxide itself is caustic and can cause skin irritation. Take your leaking batteries to the recycling centre in a plastic bag. ***LV***

GETTY IMAGES X3, ALAMY

HEATHER KENNEDY, VIA EMAIL

WHAT IS GUTTATION?

If you've walked through a meadow just after sunrise, you might have noticed tiny droplets of water arranged in neat lines along the edges of plant leaves. Although they look a bit like dew, these water droplets in fact came out of the plant.

To photosynthesise, plants need water, which they absorb from the soil with their roots, and carbon dioxide, which they take up from the air through tiny leaf pores, called stomata.

Moisture evaporates from the stomata, so plants can close these pores to conserve water at night or during drought. When the stomata are open, water constantly moves through the plant from root to leaf, and this also helps to pull more water into the roots. If the soil is very wet, then water continues to enter the roots by osmosis, even if the stomata are closed. This causes water to build up inside the roots with nowhere to go.

To relieve the pressure, plants perform guttation – they ooze sap through special pores on the edges of the leaf, called hydathodes. Guttation is most common at night or very early in the morning, when the air is cool and moist, and the soil is warm, but it can even happen during the day if the humidity is very high.

The droplets are mostly water, but they may also contain dissolved nutrients, such as salts and sugars. Often, the water droplets will drip from the leaf, but sometimes they evaporate, leaving nutrients behind as a thin white crust. If the plant has been treated with insecticides, guttation droplets may contain high concentrations of these chemicals, which can kill bees that drink the water. Guttation is generally harmless to the plant, but sometimes, the moisture can create ideal conditions for bacteria and mould to develop. ***CA***

DANIEL GRANT, SUNDERLAND

DOES GETTING RID OF MUCUS WHEN I'M SICK HELP ME GET BETTER QUICKER?

People think mucous and phlegm are things you should cough up and get out, because they're bad for you. But in truth, mucous is the interface between you and the outside world. It lines the moist surfaces of your nose, sinuses and lungs, and filters out material you breathe in – a bit like flypaper. It's mostly water, but also contains proteins, sugars and molecules that help the body control harmful germs. Mucous creates a layer of protection between us and the outside world, so it's not something to get rid of.

Although we make quite a lot of it all the time, usually you're unaware of it. It gets pushed to the back of the throat by microscopic hairs called cilia, and you swallow it without noticing. It's only when you're ill and it gets produced in excess that you might notice it more. When you're unwell, your mucous can become thicker and stickier, but it's still playing a vital role in trapping bacteria, viruses and cells that are mobilised from your immune system. So, for the most part, leaving the mucous alone is probably for the best.

Getting rid of it won't necessarily make you feel better any sooner. But the excess mucous can get a bit annoying. Keeping the air moist, using saline irrigation (using a sinus rinse, which you can buy or make yourself easily at home), gargling with salt water and staying hydrated can all help. Decongestants from the pharmacy can also help, but decongestant nasal sprays shouldn't be used for more than a week at a time, as using them for too long can actually make your stuffiness worse.

So, in short - you don't need to get rid of mucus and it won't speed up your recovery if you do. But if it makes you feel better, there's no harm. ***NM***

The Mariana Trench was formed when one tectonic plate was pushed beneath another.

The trench was first discovered in 1875 by the crew of the British ship *HMS Challenger*.

If Mount Everest was placed at the deepest point, its summit would still be 2km underwater...

...and you'd need to stack 13 Burj Khalifas, the world's tallest building, to reach the bottom.

A DEEP DIVE INTO THE...

Mariana Trench

Infographic by James Round

It's said that we know more about the surface of the Moon than we do Earth's oceans. The deepest parts of our oceans sit within the Mariana Trench and, with near-freezing temperatures and crushing pressure, make for an environment that, in many ways, is as inhospitable as space. And, just like space, this remote underwater frontier offers mysteries that we can't resist. How deep do the oceans go? What's down there? And can life exist at these depths? Over the last few decades we've begun to answer these questions and, in doing so, have revealed a strange and fascinating alien world right here on Earth.

TOTAL LENGTH	AVERAGE WIDTH
2,414km	69km

MAXIMUM DEPTH	TEMPERATURE AT THE BOTTOM
11,000m	1 – 4°C

MAPPING MARIANA

Where is the trench?

Running in a long crescent shape across the floor of the western Pacific Ocean, the Mariana Trench can be found near the Philippines, around 200km off the coast of the Mariana Islands, which includes Guam.

REACHING NEW DEPTHS

Exploring the deepest point on Earth

Within the Mariana Trench lies the deepest point on Earth's surface: Challenger Deep. It's a place that only the most intrepid ocean explorers have visited, risking their lives in robust submersibles that allow them to descend 11km (7miles) underwater and witness this incredible location with their own eyes. As submersible design has improved, the journey has become more accessible, but the simple fact remains more people have been to space than to this point on the ocean floor.

DSV *Limiting Factor*

This deep-submergence vehicle (DSV) is a state-of-the-art two-man vessel that has made multiple journeys to Challenger Deep. In 2019, it became the first crewed submersible to reach the deepest point in all five oceans and has also explored many notable ship wrecks including the *Titanic*.

DIVE DEPTH	PRESSURE TESTED TO	DIVE ENDURANCE	HULL THICKNESS
11,000m	14,000m	16 hours	90mm

DIFFERENT PLACE, SAME PROBLEMS

Pollution in the trench

Despite being one of the most remote locations on Earth, the Mariana Trench has not escaped the impact of humanity. Research published in 2019 found that 100 per cent of the amphipods from the trench that were studied had traces of microplastics in their stomachs. In that same year, undersea explorer Victor Vescovo discovered a plastic bag and sweet wrappers at a depth of almost 11,000m.

Since 1960, 27 people have ventured into Challenger Deep, the deepest part of the Mariana Trench. Below is a selection of these brave men and women...

Don Walsh and Jacques Piccard (1960)
The first people to explore the deepest known part of the world's oceans.

James Cameron (2012)
52 years after Walsh and Piccard, the *Titanic* director became the third visitor, performing the first solo dive.

Kathryn Sullivan (2020)
As no stranger to adventure, this NASA astronaut became the first woman to reach Challenger Deep.

Hamish Harding (2021)
Holds records for the longest time at the bottom (4.25 hours) and the longest traverse at the bottom (4.6km).

Less than 25 per cent of the ocean floor has been mapped. What secrets might the rest hold?

Sources: *NOAA, Wikipedia, Britannica, National Geographic, The Five Deeps Expedition, ArcGIS StoryMaps*

ALIEN ENVIRONMENTS

What lies beneath?

1 Epipelagic zone — Surface to 200m

Lots of external factors influence the ocean's top layer, including sunlight, heat and wind. The light allows algae to photosynthesise and thrive, creating over half of the oxygen in Earth's atmosphere. Algae also provides an key food source for the entire ocean, including other creatures found in this zone, such as countless fish species, jellyfish, whales and dolphins.

2 Mesopelagic zone — 200 – 1,000m

Also known as the twilight zone, visible light in this layer becomes very faint. Water temperature also decreases rapidly through a transition layer called the thermocline. Fish and a variety of invertebrates can be found throughout this zone and are all well adapted to the conditions; fish have larger eyes and some species generate their own light through bioluminescence.

3 Bathypelagic zone — 1,000 – 4,000m

At this depth, often called the midnight zone, there's complete darkness; the only light comes from the bioluminescence of the species that live there. Organisms found in this zone, including sharks, squid, octopuses and many species of fish, have adapted to a chilly constant temperature of 4°C and extreme pressures reaching almost 413 bar (6,000psi*).

4 Abyssopelagic zone — 4,000 – 6,000m

Down here, the temperature is near-freezing and the pressure can reach a crushing 758 bar (11,000 psi*). Life at these depths is more sparse, but still includes a variety of fish and invertebrates. Most of the organisms that do live here rely on marine snow (a continuous shower of mostly organic detritus that falls from the waters above) to survive.

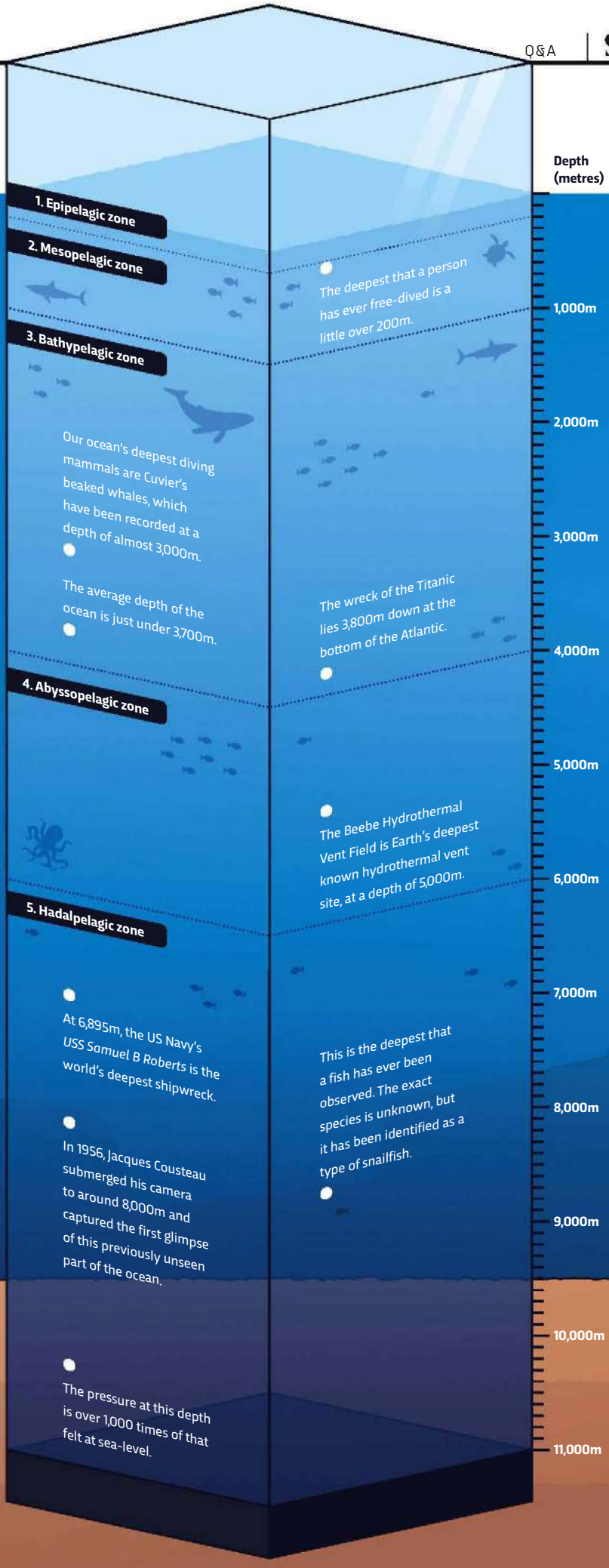
5 Hadalpelagic zone — 6,000 – 11,000m

These depths only exist in a few places on Earth. Despite near-freezing temperatures, complete darkness, nutrient scarcity and pressures reaching 1,100 bar (16,000 psi*), life still exists. A few fish species can be found in the upper part of the zone and even in the very deepest parts, invertebrates, such as sea cucumbers, and a variety of single-celled organisms survive.

**psi = pounds per square inch*

Victor Vescovo (2022)
With a total of 15 dives to his name, Vescovo holds the record for the most visits to Challenger Deep.

Image Credits:
Gage Skidmore (James Cameron), Tamara Stubbs (Victor Vescovo), Wikimedia (Kathryn Sullivan and Hamish Harding)


Depth (metres)
1. Epipelagic zone
2. Mesopelagic zone
3. Bathypelagic zone
4. Abyssopelagic zone
5. Hadalpelagic zone
1,000m
2,000m
3,000m
4,000m
5,000m
6,000m
7,000m
8,000m
9,000m
10,000m
11,000m
The deepest that a person has ever free-dived is a little over 200m.
Our ocean's deepest diving mammals are Cuvier's beaked whales, which have been recorded at a depth of almost 3,000m.
The average depth of the ocean is just under 3,700m.
The wreck of the Titanic lies 3,800m down at the bottom of the Atlantic.
The Beebe Hydrothermal Vent Field is Earth's deepest known hydrothermal vent site, at a depth of 5,000m.
At 6,895m, the US Navy's USS Samuel B Roberts is the world's deepest shipwreck.
This is the deepest that a fish has ever been observed. The exact species is unknown, but it has been identified as a type of snailfish.
In 1956, Jacques Cousteau submerged his camera to around 8,000m and captured the first glimpse of this previously unseen part of the ocean.
The pressure at this depth is over 1,000 times of that felt at sea-level.

MYTHBUSTERS

IS **'BABY BRAIN'** A REAL THING AND, IF SO, WHAT CAUSES IT?

The changes a mother's body goes through during pregnancy are complex, extraordinary and go far beyond a bulbous belly, cravings and swollen ankles. Many women also experience mental changes, such as forgetfulness, brain fog, poor attention and focus. This is commonly referred to as 'baby brain' and describes the general feeling of not being quite on the ball mentally. Scientists have proven it is real and that the brain undergoes physiological alterations.

Baby brain can strike as early as the first trimester and can last for years – even after the baby is born. Although the reasons behind it are not entirely understood, there are a few things we do know that may contribute to mothers' temporary cognitive decline.

HORMONAL CHANGES

During pregnancy, a woman experiences significant hormonal changes, including surges in oestrogen and progesterone. Elevated levels of these two hormones have an enormous impact, both physically and mentally. They can affect our ability to think clearly, focus and recall information, causing a feeling of brain fog. Studies have found that pregnant women may have particular difficulty remembering locations and spatial relations between objects, a cognitive function known as spatial memory. This explains why so many pregnant people are always searching for their car keys!

Pregnancy can also be a stressful time and heightened stress levels trigger the release of the stress hormone cortisol, which is known to affect brain function including memory, attention and decision-making.

SLEEP DEPRIVATION

Unfortunately, growing a baby and caring for a newborn is often accompanied by severe sleep deprivation. Insomnia can start early on in pregnancy and once the baby is born, sleep can become even more elusive. This can contribute to baby brain because sleep is essential for the brain to restore its energy levels and carry out important housekeeping tasks, such as removing toxic waste and repairing brain cells, ensuring we wake up feeling refreshed and energised. A lack of good-quality sleep can lead to poor memory, concentration and a general 'zombie' feeling.

PHYSICAL CHANGES IN THE BRAIN

Recent studies have found that women's brains during pregnancy undergo some astounding physical changes that may contribute to baby brain. Scientists have discovered that pregnant women's brains have dramatically reduced volumes of grey matter in the regions associated with processing social information. It's believed these adaptive changes help fine-tune and prepare the brain for maternal behaviour, such as learning to read the plethora of baby expressions and forming a strong mother-child attachment. So, while pregnant women might be losing their car keys repeatedly, they're more than equipped to care for their baby – despite the presence of baby brain.

Although baby brain is understandably frustrating and upsetting at times, it is important to note that it's a natural and common pregnancy symptom, and the mental fog does eventually clear. It's all part of the body's way of transitioning into motherhood. ***HM***

ELLIOT SAVAGE, DERBY

WHAT IS THE MIRROR TEST?

It's a test of self-recognition. Put a smudge of soot on a baby's nose and then plonk them in front of a mirror. Until the age of 18 months or so, the baby will be none the wiser. They can't identify their reflection and so don't think the soot is odd. Now repeat the exercise with a two-year-old (but good luck getting them to sit still). Most children of this age will touch the dirty mark, which psychologists interpret as a sign, not just that the child can recognise its image, but that it is becoming self-aware.

The test was devised in 1970 by American psychologist Gordon Gallup Jr, who wanted to see if animals could recognise themselves. Since then, many animals have taken the test, but only a few have passed. These include great apes, killer whales, bottlenose dolphins, Eurasian magpies, a fish called the cleaner wrasse and an Asian elephant. Animals that have failed the test include giant pandas, sea lions, parrots, New Caledonian crows, various macaques... and cats and dogs.

Dogs rely heavily on their sense of smell, so critics argue that the mirror test is unfair to dogs. A better experiment is to collect fresh urine samples from your dog and several others, and then monitor your dog's reactions to them. Researchers have found, not just that dogs can discriminate their own odour from that of other dogs, but that when that odour is tainted with an additional smell – analogous to when the babies' faces are tainted with soot – they spend more time sniffing it. This suggests that dogs can recognise themselves after all. As for cats? Good luck persuading them to do anything even remotely acquiescent! ***HP***

INDIA KELLY, VIA EMAIL

WHAT IS THE DOPPLER EFFECT?

The Doppler Effect, first described by Austrian physicist Christian Doppler in 1842, is a fundamental concept in physics. It describes the apparent change in wavelength (or frequency) of a wave phenomenon for an observer moving relative to the source of the waves.

The easiest way to understand the phenomenon is to consider sound waves. Sound is characterised by the distance between successive sound waves, its wavelength. The human ear perceives this as the 'pitch' of the sound. Short-wavelength sounds are higher pitched compared to sounds with longer wavelengths. Now, if the source of the sound is moving towards you , then the waves are squashed together and their wavelength is effectively shortened, so the pitch of the sound is higher. Conversely, if the source of the sound is moving away from you, then the waves are stretched apart and their wavelength is lengthened – the pitch of the sound is lower.

This is why the sound of a racing car, for example, goes from a high pitch to a low pitch as it approaches, passes and recedes from you. You can easily hear the Doppler Effect in operation whenever a sound-emitting object is moving relative to you – think ambulance sirens, trains, planes and so on.

All wave phenomena display a similar Doppler Effect. In the case of light, the wavelength emitted by an object moving towards you is shifted to shorter wavelengths. Since the shortest wavelengths of visible light correspond to the perceived colour 'blue', this phenomenon is known as 'blueshift' – although it doesn't necessarily mean the object in question looks blue. Conversely, if the source of light is moving away from you, the wavelength is shifted towards the red end of the visible spectrum. Hence 'redshift', but again it doesn't necessarily mean the object appears red.

The Doppler Effect has many practical applications. Doppler radar systems, which emit radio waves and detect the signals reflected by objects, can be used to track the movement and intensity of storms. This is also the principle on which speed cameras and air traffic control radars are based. Doppler sonars use reflected sound waves to measure the location and motion of objects. Some animals – bats, for example – use a Doppler technique to detect the motion of prey, through echolocation. Doppler ultrasound is a medical imaging technique that uses short-wavelength sound to measure the movement of blood through the body.

The Doppler Effect is crucial for astronomers. It can be used to determine the velocity (and sometimes rotation) of objects far away in space. Since all the light from a moving object is shifted by the same relative amount, astronomers make use of 'spectral lines' in their observations. Chemical elements in the object emit or absorb light at specific wavelengths and act as markers in the object's light spectrum. These lines are also shifted by the object's motion relative to Earth and so can be used to measure its velocity. ***AG***

QUESTION OF THE MONTH

ROBERT GREEN, VIA EMAIL

WHERE DOES THE CUCKOO LEARN ITS TERRIBLE BEHAVIOUR?

Cuckoos are master manipulators. After laying a solo egg in the nest of another species, female cuckoos abandon their offspring to the care of others. When the interloper hatches, it boots out any other eggs or hatchlings present, then tricks its foster parents into feeding it more by imitating a whole nest of chicks. The host birds then raise the chick as their own. It's a strategy known as brood parasitism, but how do they know to adopt this strategy, when they're raised without cuckoo role models?

Animal behaviour is influenced by nurture and nature, but in this instance, genetics holds the trump card. It's thought that multiple genes influence brood parasitism, and that these genes are passed from mother to daughter. So, the genes that influence a female cuckoo's parenting style (along with her preference for the species whose nest she's most likely to hijack) will be consistently passed to her offspring.

You could say that cuckoos are 'born bad,' or rather that they simply are what they are: beautiful, successful birds with an unusual lifestyle that has been honed through millions of years of evolution. ***HP***

WINNER

The winner of next issue's *Question of the Month* wins a **trio of hardback popular science books** (*Ultra-Processed People* by Chris van Tulleken; *Fevered Planet* by John Vidal; and *The Science Of Reading* by Adrian Johns), worth over £60.

EMAIL YOUR QUESTIONS TO **QUESTIONS@SCIENCEFOCUS.COM**

GETTY IMAGES X3 ILLUSTRATION: JOE WALDRON

THE EXPLAINER
BEES

THEY COULD WELL BE THE LINCHPIN HOLDING EARTH'S ENTIRE ECOSYSTEM TOGETHER... SO IT'S NO WONDER THEY'RE BUSY. HERE'S EVERYTHING YOU NEED TO KNOW ABOUT THE IMPORTANT INSECTS THAT ARE UNDER THREAT

Bees are winged insects that feed on nectar and pollen, and sometimes make honey. There are around 20,000 bee species, of which 270 live in Britain. More than 90 per cent of bee species are solitary, but the remainder, which includes honeybees and bumblebees, live socially in colonies that incorporate a single queen, female workers and male drones.

The biggest bee – Wallace's giant bee – grows up to 4cm long, while the workers of some tiny, stingless bees are smaller than a grain of rice. Bees are found on every continent, except Antarctica, and in every habitat that contains insect-pollinated flowering plants. They pollinate many of the plants that we depend on for food and yet they're in decline. The number of bee species has been decreasing for decades and, in Britain, the insects have been lost from a quarter of the places where they used to be found 40 years ago.

How intelligent are bees?

Bees are highly intelligent creatures. They can count, solve puzzles and even use simple tools.

In one experiment, bees were trained to fly past three equally spaced, identical landmarks to reach a sugary reward that was placed 300m away. When the number of landmarks was subsequently reduced, the bees flew much further, and when the number of landmarks was increased, the bees landed at a shorter distance. This suggests that the bees were counting the landmarks to help them decide where to land.

In another study, scientists created a puzzle box that could be opened by rotating a lid to access a sugar solution. When a red tab was pushed, the lid rotated clockwise. When a blue tab was pushed, it spun the other way. Not only could bees be trained to solve the puzzle, but they could also learn to solve the problem themselves, by watching other bees complete it.

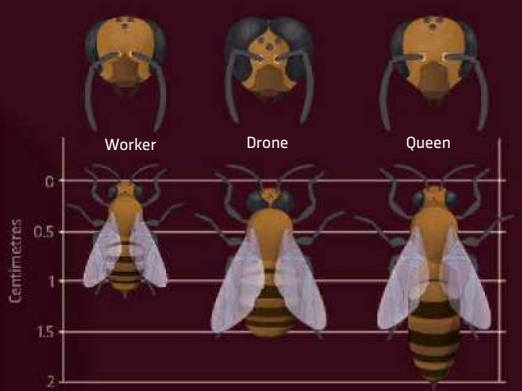
Regarding tool use, Asian honeybees are known to collect and smear fresh animal faeces around the entrance to their nest, in order to deter predatory giant hornets. It might smell a bit off, but this still counts as tool use.

Scientists had previously shown that bees can learn to use tools in the lab, but the faeces discovery from 2020 was the first observation of tool use by bees in the wild.

"Bees are highly intelligent creatures. They can count, solve problems and use simple tools"

Who's who of the hive

There are three types of honeybee within every hive: workers, drones, and a queen. The workers and the queen are female. Queens are reproductive and are larger than the workers. The drones are male, have much larger compound eyes, and do not have stingers.



The anatomy of a honeybee

The head includes...

1. Two compound eyes
2. Three smaller, single-lensed eyespots, called ocelli
3. Antennae to detect odours, tastes, sounds and temperature
4. Mandibles for chewing, most often the material used to make their nests
5. Proboscis for sucking up nectar, honey and water

The thorax comprises...

6. The midsection of the bee
7. Three pairs of legs
8. Two pairs of wings

The abdomen is where you'll find...

9. The crop, or honey stomach, for carrying nectar back to the nest
10. The stinger - a sharp organ used to inject venom

ILLUSTRATION: DANIEL BRIGHT

How do bees communicate?

Bees have two primary modes of communication: expressive dance and expressive smell.

Honeybees use the famous 'waggle dance' to direct nestmates to nectar- and pollen-rich flowers. Returning from a successful recce, a worker hurries to one of the hive's vertical honeycombs and begins to trace a figure of eight pattern. When she gets to the straight part in the middle of the shape, she vibrates her abdomen and beats her wings. This is the eponymous waggle.

The duration of the waggle indicates the distance to the flower, with each second adding an additional 100m to the journey. Communicating direction is more complicated, but can be done by the bee orienting her body in the direction of the food, relative to the Sun. The intensity of the dance indicates the richness of the food source, while the dancer also releases a cocktail of pheromones that seems to spur the nestmates into action. Colony members watch the dance, sample the odours with their antennae and then head off to find the flowers.

There are other dances, too. The waggle-less 'round dance' is used to denote the locations of flowers that are very close by, while the 'tremble dance' is performed by forager honeybees to recruit colony members to collect nectar from the workers.

"Wasps made their debut during the Jurassic Period, followed by bees in the Cretaceous Period, between 145 and 66 million years ago"

What does a bumblebee nest look like?

Bumblebees are the plump, furry bees that look as though they shouldn't be able to fly. Britain has 24 species, six of which are parasitic and 18 that are social. Social species, such as the garden bumblebee, form colonies and build nests in sheltered spots, away from direct sunlight. Abandoned rodent burrows and compost heaps are good places, as are bird boxes, holes in trees and the spaces underneath sheds.

Unlike honeybee nests, which are elaborate structures with hexagonal cells, bumblebee nests are scruffy structures with disorganised cells. Often insulated with leaves or bits of animal fur, they're designed to hold small numbers of bees (around 40 to 400) for a single nesting season. Honeybee nests, in contrast, can house up to 40,000 individuals and can last for years.

Parasitic bumblebees, such as the aptly named red-tailed cuckoo bee, don't make nests of their own. Instead, their queens invade the nests of other bumblebees, where they kill the resident queen and lay their own eggs, which are then raised by the resident workers.

How do bees navigate?

Bees often travel miles to forage in faraway flower patches, and yet are able to find their way home with unerring accuracy. All this, with a brain that's smaller than a sesame seed. So how do they do it?

Firstly, they use the Sun as a compass. Bee eyes are sensitive to polarised light, which can penetrate thick cloud. This means that even on a cloudy day, bees can still 'see' the Sun and use it as a guide. The position of the Sun is combined with an indication of time from the animal's internal clock, enabling the bee to keep track of both direction and distance.

The bee also monitors how much the Sun moves during the journey, so when she returns to the colony she can tell her nestmates the position of the food relative to the Sun's current position, rather than its position when she found the food.

Finally, honeybees are known to be able to sense magnetic fields, through some sort of magnetic structure in their abdomens. So researchers think that bees may also use Earth's magnetic field to help them navigate.

When did bees evolve?

Wasps are reputedly sadistic and generally reviled, while bees are seen as benevolent and widely adored – yet bees evolved from wasps.

Bees belong to the order *Hymenoptera*, which also includes sawflies, ants and wasps. The oldest known *Hymenopteran* fossils are from the Triassic Period, around 224 million years ago. Wasps made their debut during the Jurassic Period, between 201 and 145 million years ago, followed by bees in the Cretaceous Period, between 145 and 66 million years ago.

Trigona prisca was one of the first. A stingless honeybee found immortalised in New Jersey amber, it was on the wing around 85 million years ago. The key specimen is a female with a small abdomen, which indicates that she was a worker, and that some bee species had already organised themselves into complex social structures.

The first animal-pollinated flowers had already evolved by this time and were being pollinated by beetles, but the evolution of bees drove the evolution of flowering plants, which drove the evolution of bees, and so on. It's one of the finest examples of coevolution. Flowers evolved nectar and funnel-shaped heads, while bees evolved longer tongues to sup the nectar, and specialised hairs to transport the pollen.

KIM TAYLOR/NATUREPL.COM, JOHN WATERS/MINDEN, NICK UPTON/MINDEN, GETTY IMAGES

ABOVE Bees navigate by referencing their position relative to the Sun
OPPOSITE, TOP A honeybee performs the 'waggle dance'
OPPOSITE, BOTTOM Tree bumblebee nests, one in a tree (above) and one in a bird box

FIVE COMMON BEE MYTHS... BUSTED

1.

BEES ARE TOO HEAVY TO FLY

This myth can be traced back to the 1934 book *Le Vol des Insectes* by Antoine Magnan, who erroneously believed that bee wings are too small to generate the requisite lift for flight. He was wrong, obviously.

2.

ALL BEES STING

Male bees can't sting. The stinger is a modified egg-laying device and is only found in females. There are also around 550 species of stingless bee, which have stingers so small that they can't be used defensively.

3.

BEES DIE AFTER STINGING YOU

Of the bees that can sting, only honeybees die after stinging. Barbs in their stingers get snagged in the victim's skin and as the bee tries to free itself, its abdomen becomes fatally ruptured.

4.

ALL BEES MAKE HONEY

Most bees don't make honey. In fact, there are only eight species of true honeybee that make large amounts of the sweet stuff. There are hundreds of other bee species that make it too, but in much smaller quantities.

5.

ALL BEES ARE HARD-WORKING

As busy as a bee, right? Queens lay up to 1,500 eggs per day. Worker bees forage, feed the young and spruce up the hive. Male bees, however, don't have much to pack into their day. A drone's one and only role is to mate with a virgin queen.

Can humans live without bees?

Probably, yes. But the disappearance of bees would pose a serious threat to global food security and nutrition.

One out of every three mouthfuls of food we eat is dependent on insect pollinators, such as bees. Whether it's staples, such as potatoes and onions; fruits, from apples to watermelons; or seasonings, like basil and coriander, bees help to fertilise plants when they transfer pollen between them. Coffee and cocoa plants, for instance, both depend on bees for pollination, as do around 80 per cent of European wildflowers.

Bees are also a source of food for many birds, mammals and insects. If we lost the bees, we would lose the roles they play in their ecosystems, with knock-on effects for many other animals and plants.

It's bad news, then, that bees are in global decline. Habitat loss, intensive farming methods, pollution, pesticide use, disease and climate change are all to blame. And a recent study found that the global loss of pollinators is already causing around 500,000 early deaths a year in humans, by reducing the supply of healthy foods.

"Coffee and cocoa plants both depend on bees for pollination"

What should I plant for a bee-friendly garden?

Most bee species aren't too fussy about where they get their pollen and nectar from, so plants such as lavenders, hollyhocks and marigolds will attract a good range of bees. Other species, however, are more specialist and depend on a smaller number of plants. These bees are often rare and if the plants that sustain them disappear, then the local population may be at risk.

Grow yellow loosestrife (right) for the yellow-loosestrife bee, a medium-sized bee that frequents the plant for its pollen and scented oils. Females use the oils to waterproof their nests, which can often be found on the edges of ponds and rivers. Lamb's ears are an easy-to-grow, evergreen perennial favoured by the wool-carder bee. Female wool-carder bees use fibres from the soft, furry leaves to line their nests, while males defend territories that contain these plants.

Another easy option is to let your lawn grow long and embrace the weeds. Dandelions and related plants, such as hawkbit and hawkweed, are a favourite of the pantaloon bee, which gets its name from long hairs on the females' hind legs that get coated in pollen and look like clown trousers. Similarly, buttercups are a magnet for large scissor bees and sleepy carpenter bees.

PHIL SAVOIE/NATUREPL.COM, NICK UPTON/NATUREPL.COM

by DR HELEN PILCHER (@helenpilcher1)
Helen is an author, speaker and science communication consultant with a PhD in cell biology.

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CROSSWORD

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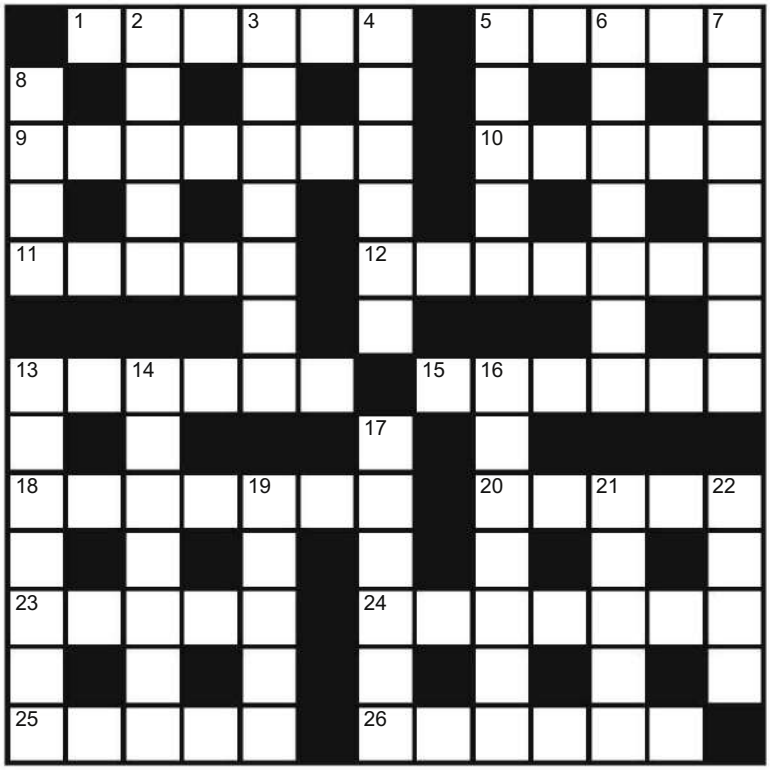


ACROSS

1 Difficult to deceive your head (6)
5 Reappear concerning dog (5)
9 Business worry (7)
10 Guerrilla's beginning fire, spreading trouble (5)
11 Hawk circles river for fish (5)
12 Conclusion not quite so infinite (7)
13 British riots set out in restaurant (6)
15 Stretch betting on inexperienced learner (6)
18 Low gags about city (7)
20 Film about British insurgent (5)
23 Moving stair into new arrangement (5)
24 Model a clipper badly, lacking front of prow (7)
25 Germany's top beer intoxicated bird (5)
26 Set tea out in the grounds (6)

DOWN

2 Composer on doctrine about musical form (5)
3 Inventor of strange reactor (7)
4 Rodney runs that way (6)
5 Seethed at bad grade (5)
6 Care about taking that guy to be a monster (7)
7 Judge country left in denial (7)
8 Cost upsetting a Brit (4)
13 Astronomical theory making quite an impact (3,4)
14 Rattles angrily in surprise (7)
16 Soldier at favourite wall (7)
17 Points to ever-changing deviation (6)
19 Blood around small shrub (5)
21 Constructed one large objection outside (5)
22 Boy has nothing to pack (4)

ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

ESO

NEXT ISSUE

EXTRATERRESTRIALS

Delve into the conditions needed for life to exist on other planets

PLUS

THE WOLF IN YOUR FRONT ROOM

Find out how domesticated dogs really are... and whether your pet pooch thinks they're your best friend

CONCORDE REBORN

Meet the engineers working to resurrect supersonic passenger flight

ON SALE 27 JULY

SF

POPCORN SCIENCE

Could one bomb destroy the world?

How big a bang are arms manufacturers capable of creating?

by STEPHEN KELLY

There is a scene in Christopher Nolan's new film *Oppenheimer* (a biopic of J Robert Oppenheimer, the man who invented the nuclear bomb) in which Leslie Groves, an army engineer played by Matt Damon, worries about destroying the world. This is just before the Trinity test, the first-ever detonation of an atomic bomb, and Oppenheimer says he's confident that the chances of annihilating all life on Earth are near zero. "Near zero?" splutters Groves. "Zero would be nice!"

In reality, Groves's concerns were those of Manhattan Project physicist Edward Teller. According to Steven Biegalski, Chair of Nuclear and Radiological Engineering at Georgia Institute of Technology, Teller was worried that the heat of the explosion "would cause the hydrogen in the atmosphere to undergo fusion, setting off a catastrophic chain reaction that would continue around the globe and destroy Earth." In other words: there was a fear that it would set the world on fire. "This obviously did not happen," adds Biegalski. "The density of fusible atoms and the energy balance prevent it from happening."

Still, it raises the question: how big and destructive can nuclear weapons get? Could a single bomb feasibly end the world?

"The bomb dropped on Hiroshima during World War Two was 15 kilotons, equivalent to 15,000 tonnes of TNT," explains Tara Drozdenko, a director of the Global Security Program at the Union of Concerned Scientists. "The Nagasaki bomb was 20 kilotons. Most current US nuclear weapons are 15 to 20 times more powerful than those bombs".

For context, the Hiroshima bomb devastated 13km² of the city, destroyed 63 per cent of its buildings and killed at least 70,000 people. But the most powerful nuclear bomb ever made was tested by the Soviet Union in 1961. Named Tsar Bomba, it had a yield of over 50,000 kilotons, which is equivalent to 50 million tonnes of TNT. The blast was monstrous, destroying houses in the village of Severny, 34 miles from the testing site at Mityushikha Bay. If such a bomb were dropped on Manchester, people in Liverpool, Leeds and Sheffield would suffer third-degree burns. Incredibly, Tsar Bomba was designed to be twice as powerful (100 megatons), but was scaled back to mitigate radiation effects.

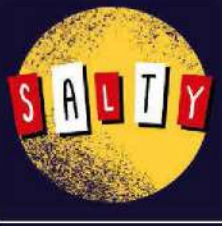
As Drozdenko explains, however, there is such a thing as too powerful. "That bomb is just not practical for an arsenal," she says. "There is no practical delivery system for it."

Such a bomb would be too big to be deployed as a missile and carry enormous risks for any crew hoping to drop it by plane. "Even at 50 megatons, there was some question of whether the Tsar Bomba plane would be able to escape the area before it exploded," says Drozdenko. "Why would you manufacture something that big if you could get 50 other ones that are smaller?"

According to Biegalski, there is a "general consensus that fission-fusion weapons can go to much higher yields than Tsar Bomba". There is even speculation that in the future they could be used to knock an asteroid off course. Yet there are limits to how powerful a single bomb can be.

"There is always a maximum for two reasons," says Biegalski. "One is that you can run out of material to put in the bomb. Two, at a certain stage the bomb blows itself apart and the reaction stops."

As for whether a "theoretical-maximum-size nuclear weapon" could destroy the world, Biegalski is uncertain. "All I know is that I hope we never go there," he says. **SF**



VERDICT

Whether a single bomb could destroy the planet is unclear. But for practical reasons, we're unlikely ever to build one that could. Phew!

by **STEPHEN KELLY** *(@StephenPKelly)*
Stephen is a culture and science writer, specialising in television and film.

ILLUSTRATION: NEIL WEBB

This was Sylvia's promise to you...

A generation ago, a woman named Sylvia made a promise. As a doctor's secretary, she'd watched stroke destroy the lives of so many people. She was determined to make sure we could all live in a world where we're far less likely to lose our lives to stroke.

She kept her promise, and a gift to the Stroke Association was included in her Will. Sylvia's gift helped fund the work that made sure many more of us survive stroke now than did in her lifetime.

Sylvia changed the story for us all. Now it's our turn to change the story for those who'll come after us.

Stroke still shatters lives and tears families apart. And for so many survivors the road to recovery is still long and desperately lonely. If you or someone you love has been affected by stroke – you'll know just what that means.

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